PRACTICAL GEOMETRY
OR
A Manual of Mathematical *RECREATIONS.*

Shewing how to perform ſome ſelect Propoſitions of *Geometry*; With the deſcription and making of a *Quadrant*, by which any of ordinary capacity, by their own enduſtry, may (exactly and ſpeedily) find the Suns declination, Amplitude, Altitude, Azimuth and hour of the day, &c. at all times, and in all places, both by Sea and Land.

As alſo how to find the true heights, depths and diſtances of Hills, Caſtles, Towers or Steeples, whether acceſſible, or inacceſſible, without approaching the ſame: Together with uſeful Inſtructions, for Water-Levels, Coalheughs, and Water-works, *&c.* And how to draw an Horizontal Dial for any Latitude.

Fitted for the ingenious of all Ranks aud Profeſſions, whether Military, or Civil: but principally for Artificers, Maſſons, Wrights, Surveyors of Lands or Buildings, Engineers, Military Architects, Gunners, Myners, and all other Students in the Mathematicks.

By *JAMES CORSS* Mathematician.

Printed at *Edinburgh* by a Society of *Stationers*, Anno 1666.

NATIONAL LIBRARY
OF SCOTLAND
EDINBURGH

To the Reader.

GEometry *is ſo excellent a* Science, *that there is no Precept or Rule therein, which may not be palpably proven by real* Demonſtration, *to evince the* Infallability *thereof: in regard of which, it may juſtly challenge (as due) the priority of other* Sciences; *for all other* Arts *muſt borrow their* Demonſtrations, *(for* Illuſtration *of their (various)* Hypotheſis *) from undeniable* Geometry. *This Art of* Geometry *hath properly its name from* meaſuring the Earth, *and had (alſo) its firſt* Production *and* Original *in* Ægypt; *for when* Nylus *with his inundation had drowned and confounded the limits of the* Lands, *then certain of the moſt ingenuous Inhabitants were neceſſitated to finde out the* Rules *of* Geometry *by help whereof, (after the fall of the water) every man had his own (exact) portion of land reſtor'd to him again. From* Ægypt *it came to* Greece, *and ſo ſpreading it ſelf over the* Univerſe, *it became more common.*

But to omit its Antiquity *and* Excellency, *&c. I ſhall only ſpeak (briefly) of its* Utility *and* Benefite, *which is ſuch, that (I'm ſure) there's none (intelligent) will deny it. For it's of ſuch ſingular importance, in* time of Peace, *that without it, we cannot preſerve our ſelves from manifold* Inconveniencies, Prejudices *and* Dammages *in our ſeveral (of the moſt ingenious)* Trads *and* Incorporations; *nor can we rectifie our* Prior Irregularities, Confuſion

ſuſions *and* Diſproportions, *but by means thereof. And in time of* War, *(whither it be* Offenſive *or* Defenſive, Forraign *or* Domeſtick*) without it, it's impoſſible, either to ſecure our ſelves from* Danger, *or beat our* Enemies. *But by means of* Geometry, *the* Millitary Architect *may fabricate his* Forte, *after ſuch a* Form, *and* decent Geometrical proportion, *that (all circumſtances duely weighed) no force (*viz. *neither* Battering, Storming, Wind *nor* Water*) ſhall reduce the defendants*: Hunger, Cowardize *and* Folly *excepted.*

Yea, by help of it, the General *may embattail his* Army *in the moſt imaginable poſture of War, either Offenſive or Defenſive*; *The* Engeneer *may plant his* Cannon, *conduct his* Myne, *and preſent his* Execution, *to the terrour and diſadvantage of his* Enemy: *The* Navigator *or ſkilful* Skipper *can typifie his various* Traverſes, *and demonſtrate thoſe* Roads *(though inviſible) which he makes through the confuſed and violent* Surges *of the* Ocean: *The compleat* Dyaliſt *can trace out the way of the Sun upon the Earth, and by the ſhadow of an* Axis, *to point out (unto us) thoſe* Atomes *of* Time *into which our* Artificial *day is (*Artificially*) divided. In a word, there's no* Trade *or* Function *whatſoever, that deſerves the Epithete of* Ingenuity, *but requires aid of* Geometry, *neither do they Mannage and Practice their Profeſſions without it, (although themſelves be ignorant of it,) which I could ſufficiently evince in every Handy-craft, were it not that I love Brevity.*

For the time would fail me to repeat its various

Uſes

Uſes and Applications, and therefore I ſhall willingly wave it, and come to ſpeak more particularly of the Book enſuing, which I ſeriouſly recommend to your Peruſal, without any Complements for Acceptation; becauſe, look what Proportion your Underſtanding and Knowledge hath to the things contain'd therein: So much (and no more) will your Acceptation and Approbation be thereto. If you Read and Practice, what I have here written, you ſhall find the Operations infallible, though diverſly performed. Some are reſolved Geometrically *by Rule and Compaſſe only, without the aid of* Arithmetick.: *Others Inſtrumentally,* viz. *by a* Quadrant, *fitted for the purpoſe, (the making whereof, I have ſufficiently demonſtrated in the* Sequel) *which requires the help of* Arithmetick. *I have been as plain as poſſibly I could both wayes, inſomuch, that (I ſuppoſe) the moſt Ignorant (for whoſe ſakes I principally intended it) cannot but Underſtand and Practice the ſame. A little difficult at firſt perhaps it may prove, but yet (as the diligent Hand makes rich, ſo) the frequent Reading and Practizing will induce you to the knowledge thereof.*

And for your ſooner Attainment thereto, I have not only given you the ſeveral Precepts, but alſo (for better Illuſtration) their reſpective and particular Demonſtrations, deduced from infallible principles of Geometry : *So that not only Reaſon, but Common Senſe will confirm the Truth thereof, what remains then? but your Practice to prove all. I have been at a great pains (eſpecially in cutting*

the

the Typs, of which Art I was never taught) but take you all the Profit, for a ſmall Practice. Sure I am, the Ingenious will; and for others, 'tis not to be expected.

However, I am reſolved (maugre the powers of Malice and Envy) to be helpful to my Country, in ſuch Mathematical Arts and Sciences, as I have ſpent my Studies about. If I hide my Talents, I am not ignorant what became of that ſervant that wrapped up his in a Napkin, and buried it in the Ground. I do ſeriouſly proteſt, that if I fail at all, it's only in Power, not in Good-will; and I hope God will accept the Will for the Deed.

A few words more and I have done, and that is (for your better underſtanding of the Elements and Propoſitions of Geometry) to Read and Practice often the firſt five or ſix Chapters, which being once underſtood, the reſt will become more Facile. And laſtly, if you meet with any Errata's of whatſoever nature, I mean, whither Literal, Syllabical, Dictional, or Sententional, I requeſt thy courteſie to amend it with thy Pen, omitting all Cenſorious Imputations; for my only aim in this Treatiſe, is to inſtruct the Ignorant, who either loves, or deſires to be Taught, the knowſedge of theſe things. To whom I wiſh (all) proſperous ſucceſſe in this, and all other honeſt Endeavours: and for whoſe ſakes, I confeſſe my ſelf to remain a ſervant to all the (TRUE) lovers of ART.

From my Houſe at the foot of *Nidries* wind, neer the *Iron-Cannon*, *Jan* 24. 1666.

JA. CORSS.

In, Ingenioſiſſimi ac eruditiſſimi amici Magiſtri *Jac. Corſs*, Mathematicorum oblectaminum Enchiridium.

NUnc bene perducta ad ſummum Mathematica culmen
In te ſtat, Nec quo progrediatur, habet.
Digna quidem tanto, præconia dicere libro
Vix queo, O Patrii luxque decuſque ſoli.
Eſt equidem liber exiguus, quemque ære juventus
Emere quæque poteſt exiguo facile:
Sed non exiguum eſt quod continet ille profecto;
Ingenii multumque utilitatis habet.
At prodire novos hac tempeſtate libellos
Vidi equidem, qui nil utilitatis habent.
Sed producuntur verborum ambagibus, & quos
Legere, jactura eſt temporis indubie.
Tu tamen eſt ſummo Celebrari dignus honore;
Scripta Cunctorum qui uſibus apta facis.
Laus tibi debetur, quod tu Geometra profunde
Hic varios, multâ comperis arte, modos.
Vive igitur fœlix longos (Jacobe) per annos;
Ac aliud, docto pectore profer, opus.
Sis fœlix licet, uſque tuis decus, atque perennis
Famæ, nos donec mittet in aſtra dies.

Ἐκ φόνε τὸ κλεός.

Mr. IOANNES MILLAR.

*

O
Hoe
From
VVhom
Can wee
Light SEE
More Cleare
In our SPHERE
Then from our Corſs?
Who doeth Indorſs
ARTS *noble and ſublime*
So plain in this our time:
That he who pleaſes to beſto
Some pains upon himſelf, To kno
The MATHEMATICK *Miſteries:*
In LINEA and PERIPHERIES
Let him, I ſay, that hath ſuch a deſire
Be bold to come & read, a little nigh'r
And Pry into this Book. *In it he'l find*
Variety, *that ſhall Content HIS mind.*
And if HE Gain by this (as I Doubt not)
How ought HE then, give Honour to our SCOT.
That after darkeſt Dayes, Urania *hath brought in*
To teach his Country equally, and thereby Glory win.
Go on brave Soul, *reſume more works: that our* Poſteritie
And after Ages, may with joy; Honour thy Memorie.
Then may our Caledonia *boaſt, that from her Boſom's flown*
The Peerleſs Naper *& our* Corſs, *with Bayes deſerves a Crown.*

A Pyramide Erected and Dedicate in honour of his very worthy friend, Mr. *James Corſs* Mathematician, Author of this *Practical Geometry*, &c.

By *John Hammiltoun*, a lover of the Mathematicks.

Upon

Upon my much honoured and ingenious Friend *JAMES CORSS* Mathematician, his *Geo. Practica.*

MOst famous *Corss*, I freely must confesse
That *Fancie* finds a check from an *Excess*
Of thy great *Merits*, which none can rehearse
An matter fit for *Chronicle*, not *Verse*.
Who best do write thy *Praise*, will only leave
A *Character* of all he could *conceave*.
But none of thee; for in a word thou's one
Whose *worth* is far beyond our *Horizon*;
I need not then *attempt* thy *Praise*, who's *fam'd*
So by thy *Works*, that thou art prais'd when *nam'd*.

Mr. *JOHN MILLAR.*

An Acrostick upon my truely vertuous and most ingenious Friend, Mr. *JAMES CORSS* Mathematician, Author of this *Pract. Geom.*

I AMES, there's no *Poetry* can speak thy *Praise*
A s thy own *Works* do; They thy glory raise
M ore *highly* then the *Muses* can: Should I
E ndeavour it then? No, for none shall spy
S o much as one, that will thee praise deny.

C ORSS, thy rare *Book*, shews *distance*, *length* and
O f *Hills* and *Mountains*, & all *objects* right (*height*
R emote from us: Nay, more then that, I see
S uch strange *effects*, wrought by thy *Geometrie*
S hal *blaze* thy name, & with *Bayes* crown'd shal be.

THOMAS MACKCONVY.

Upon my Honoured Friend, Mr. *James Corſs* the Author hereof.

LEt *Duſt* ly dead, Let Divine ſparks aſpire
To meaſure out the total Magnitude.
But who can Meaſure, all mens full deſire?
Or Number it in final Multitude?
What Quantity can ſatiate thy minde?
What Quality can ſatisfie thy will?
To what Dimenſion is thy mind confin'd?
What Multitude, (its Amplitude) can fill?
In this thy Book thou mak'ſt thy Recreation
Geometry, exactly to *define*
By *dextruous* ART, and real Demonſtration,
Engraving Types, to make thy ART to ſhine;
Thou *Cuts*, thou *Carves*; Thou ſpares no *time* nor (pains
Thy *Gifts* and *Parts*, thou freely do's *employ*
To profit *others*, with thy *profound* ſtrains
(If all ſhould fail) thou do's thy ſelf *enjoy*.

ALEXANDER AUCHMUTIE

a lover of the Mathematicks.

GEOME

The Contents.

CHAPTER I.

Containing a short Explanation of the Terms of Geometry. page 1

Chap. 2. *To draw a Parallel Line, to any other Line given, at any distance required.* p. 3

Chap. 3. *To raise a* Perpendicular *Line upon the end of a Line given.* p. 9

Chap. 4. *To raise a* Perpendicular *Line, from the middle of a Line given.* p. 10

Chap. 5. *To let a* Perpendicular *fall from a point point assigned, unto the middle of a line given.* p. 11

Chap. 6. *How to make a Line of Chords, and equal parts.* p. 13

Chap. 7. *To make an Angle containing any Degrees assign'd: Or to measure the degrees of any Angle made.* p. 15

Chap. 8. *To finde the Altitude of the Sun, by the shaddow of a Staffe, or any other* Gnomon. p. 16

Chap. 9. *Sſhewing the Latitude of the moſt Principall Cities, and Towns in* Scotland, England, *and* Ireland. p. 17

Chap. 10. *To project the Sphere in Plano, for any Latitude.* p. 20

Chap 11. *To draw an Horizontal Dyall for any Latitude, or place of the Earth whatſoever.* p. 23

Chap. 12. *To find the Hour and minut of the day, in any part of the World,* Geometrically *without Inſtrument.* p. 29

Chap. 13. *To finde the Suns Azimuth* Geometrically. p. 31

Chap. 14. *How to finde the true* (Perpendicular) *heighth of a Hill, Caſtle, or Tower, that is Acceſſible, or Inacceſſible, without any Inſtrument.* p. 34

Chap. 15. *Shewing how to find the exact length, or diſtance to any Mark or Object, that's viſible on the Land, bee it never ſo far, and that without Inſtrument.* p. 37

Chap. 16. *Containing a Succinct Deſcription of the* Geometrical *Quadrant, and of the manifold uſes thereof.* p. 40

Chap. 17. *To finde the Suns Declination with Inſtrument, and without Inſtrument.* p. 42

Chap. 18. *To finde the Suns Amplitude with, and without Inſtrument.* p. 46

Chap. 19. *To find the Suns heighth in the Verti-*

call Circle, with, and without Inſtrument. p. 48

Chap. 20. *To find the Suns Altitude, or Depreſſion, at the Hour of Six, with, and without Inſtrument.* p. 50

Chap. 21. *To finde the Suns Azimuth, by the Quadrant.* p. 51

Chap. 22. *To finde the Hour of the Day by the Quadrant.* p. 54

Chap. 23. *To finde the Declination of any Wall, or Plane, by the Quadrant.* p. 57

Chap. 24. *To finde the exact heighth of a Hill, Tower, Caſtle, or Steeple, that is Inacceſſible: by the Quadrant.* p. 63

Chap. 25. *To finde the exact diſtance to the* Perpendicular *Baſe, and Top of any high Hill, Caſtle, or Tower, by the* Geometrical *Quadrant.* p. 69

Chap. 26. *To know exactly how far any Ship, Mark, or other Object, is diſtant from you: Your ſelf ſtanding on ſome high Tower, Caſtle, or Hill, by the Sea-Coaſt.* p. 72

Chap. 27. *To finde the diſtance to any viſible Mark or Object in the Field, both Geometricall, Arithmetically, and according to Trigonometry.* p. 76

Chap. 28. *To know what part of the external Superficies of a Hill-ſide, is Level with the bottome of a Coal-heugh, or Stone Quarrell, that is digg'd thereon.* p. 83

Chap.

Chap. 29. *To finde the Suns Azimuth, and hour of the day moſt exactly, eaſily and Artificially without any Inſtrument: Otherwiſe then is taught in the* 12, 13, 21 *and* 22 *Chapters.* p. 89

Chap. 30. *How to Conduct Water from any Spring or Fountain, to any place, and to find the difference of Levells.* p. 93

Chap. 31. *How to make Water in a Heugh or Pit continually to aſcend (by means of a Ciſtern only) without ſtrength or the help of Buckets or Pumps.* p. 96

GEOME-

GEOMETRIA PRACTICA,
OR,
A Manual of Mathematical *RECREATIONS.*

CHAPTER I.

Containing a ſhort Explanation of the terms of Geometry.

SEeing I ſhall have frequent occaſion, to mention ſome Geometrical Terms (which cannot properly be omitted) in the Sequel; and leſt they ſhould prove either dark or difficult to the Readers underſtanding, therefore I adjudge it neceſſary in the firſt place, to make a ſhort explanation of them; that thereby the ignorant and unlearned (for whoſe ſakes this is principally intended) may (with the greater facility) attain to a perfect knowledge, of the whole Geometrical Practices contain'd therein.

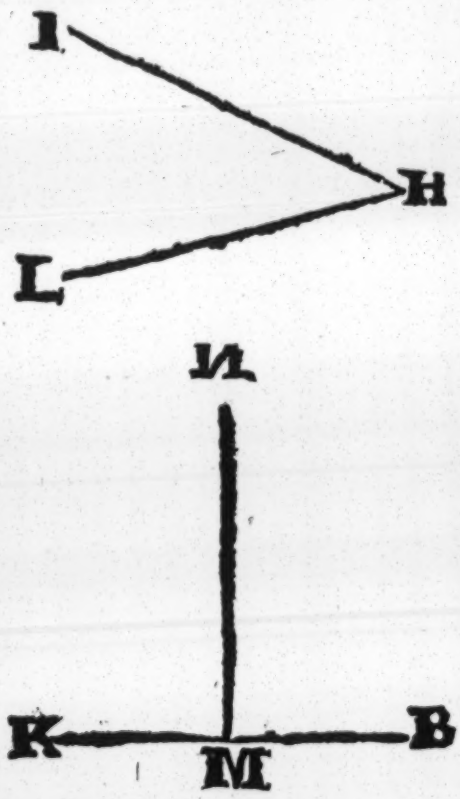
Firſt therefore, A *Point* or *Prick* is that which is the leaſt of all Materials, as being void of length, breadth and depth, having neither part nor quantity (expreſſible in numbers,) and therefore it admits of no diviſion, but

but that which is mentall onely. This point or prick is represented unto you by the letter A.

2. A *Line* is a thing extending it self in length, without breadth or thickneſſe, (whether it be a ſtreight Line or crooked) and (in reſpect of its length) may be devided into parts, but will admit of no other Deviſion, but into Lengths only, as is ſet forth unto you by the Line A B, the extreams whereof is A and B.

A ——————————— B

3. An *Angle*, is nothing elſe but the meeting of two lines, in any ſort, that they make both not one line. As here in this example, ſuppoſe the lines I H, and L H, to be ſo drawn, as they may both meet in the point H, ſo ſhall the point H be the angle included between the two lines, as, I H L.



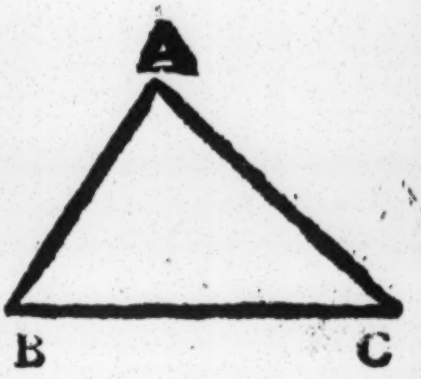
4. If a right line fall on a right line, making the angles on either ſide equal; each of thoſe angles are called right angles, and the line erected, is called a *Perpendicular* line unto the other. As for Example, the line N M, here in this Figure, falling upon the line, K B in ſuch ſort, that the angles on both ſides are thereby made equal, as here you ſee, and therefore they are called right angles, or more vulgarly ſquare angles.

5. A *Perpendicular* line, is that which ſtands plumbe upright upon (or from) another line, without leaning or inclining to one ſide, more then to the other, as you may ſee in the former figure, where the line N M is

Perpend

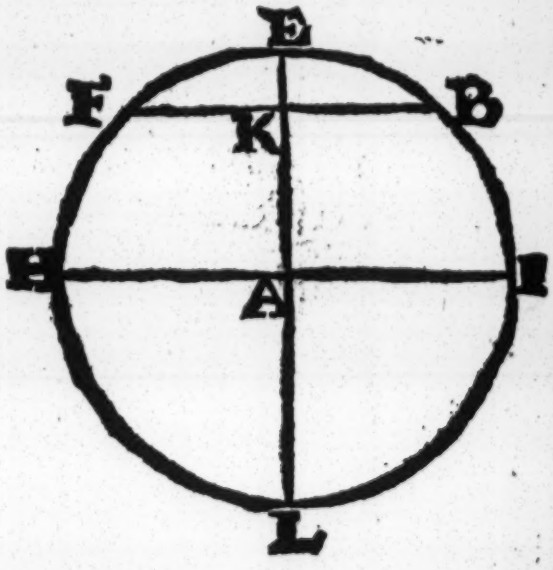
Perdendicular unto the line K M B, making equal (ſquare) angles in the point M.

6. A *Triangle*, is the interſection of three ſtreight lines, ſo as they have three angles made thereby. As for example, in this figure A B C. the three ſides, *viz.* A B, A C and B C are all right lines, and ſo drawn, as they make the three angles, *viz.* A, B, and C. and here note, that an angle is uſually deſcribed by three letters, of which three, the ſecond or midle letter, alwayes repreſents the angle intended.



7. A *Circle* is a moſt perfect figure, circumſcribed with a line, which is called the *Circumference* thereof, as in the figure following, the very ring H F E B I L is called the *Circumference* of that *Circle*.

8. The *Center* of a *Circle*, is that point which is in the midſt thereof; from which point, all right lines drawn to the Circumference are equal, as you may ſee in this figure, where the point A, repreſents the Center, which is the very middle point, upon, and by which the circumference H F E B I L was drawn.

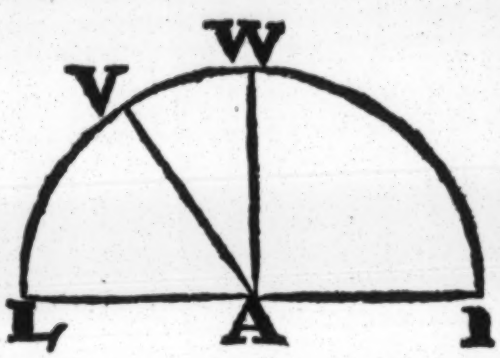


9. The *Diameter* of a Circle, is a ſtreight line drawn through the Center of a Circle, ſo as it may divide the whole Circle into two equal parts: As here in this example, you may ſee the lines H A I, or E A *L*, either of which is the Diameter of the Circle H F E B I L, becauſe

becauſe both of them paſſeth through the Center A, a divides the whole Circle H E I L, into two equal part

10. The *Semidiameter* (or *Radius*) of a Circle, is no thing elſe but the juſt half of the Diameter, and is co tain'd betwixt the Center, and the one ſide of th Circle, as the lines A I, or A E, or AH, or A L, a either of them the Semidiameters (or Radius) of th Circle H E I L.

11. A *Semicircle* is the one half of a Circle, bein drawn upon his Diameter, an is contain'd upon the ſuperfi cies or ſurface of the Diameter As for example, in the forme diagram, the ſemi-circle HEI is the juſt half of the Circl H E I *L*, and is contain'd abov the Diameter H A I, as aforeſaid.



12. A *Quadrant* is the fourth part of the Circle: A for example, when through the Center A, you dra the Diameter H A I, it divides the whole Circle int two equal parts, then from the ſaids Center A, if yo raiſe the Perpendicular A E (as afterwards I ſhal ſhew you) ſo, as to divide the ſemi-circle H E I, o H L I, into two equal parts: Then will I A E, E A H H A *L*, or L A I be either of them Quadrants, or th fourth part of the Circle H E I L.

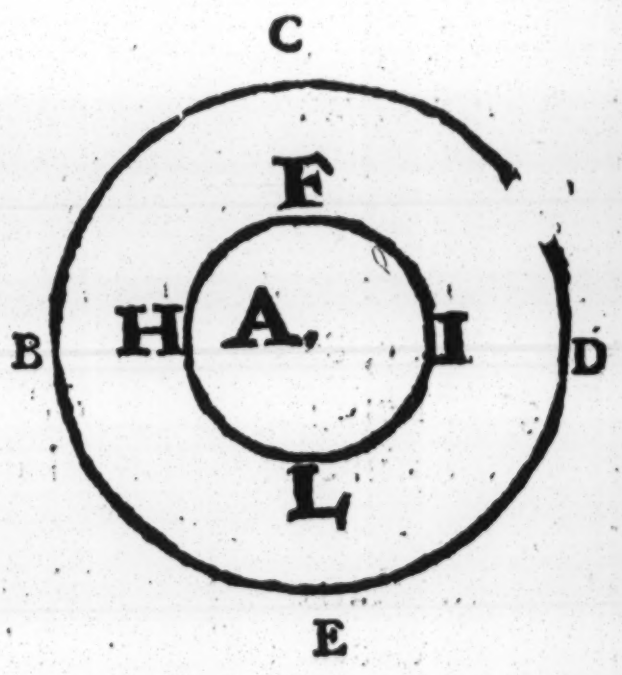
13. A *Segment* (or part) of a Circle, is any quan tity of a Circle, which is leſſe then a ſemicircle. A for example, in the former figure H E I L, you may ſee that F E B K is a ſegment or part of the Circle H E I L, and is leſſe (in quantity) then the ſemicircle H E I A.

14. A *Parallel line*, is a line drawn by the ſide of another

another line in such sort, as that the one line may be equidistant to the other line, in all places: of such parallels, there is commonly used these two sorts, *viz.* a right lined parallel, and a circular parallel.

15. Right-lin'd *Parallels*, are two streight lines, so drawn, as they are equidistant in all places one from the other, so that although they were infinitly extended, yet could never meet as may be seen by the lines B and C.

16. A circular *Parallel*, is a circle drawn either within or without another circle, upon one and the same center, as is seen by the two circles, *viz.* HFIL, and B C D E, being both drawn upon the same Center A, and therefore are parallel the one to the other.



17. All *Circles* whatsoever (whether great or small) are devided into 360 equal parts; each of those parts is called a *Degree* of which, the semicircle contains 180. and the Quadrant 90. degrees.

18. Every *degree* contains 60 minuts, being understood of measure; But in time, the whole day and night (or from noon this day, to noon the morrow) contains 24 hours, every hour contains 15 degrees,

every degree contains 60 minuts, every minut 60 seconds, &c. unto tenths.

19. The *Base* of any thing, is that part of a House, Tower, or Castle which is most inferiour, I mean, which stands even off and on with the ground, whereon you stand.

20. The *Perpendicular altitude* of a Hill, Castle, or Tower, *&c.* is nothing else but the height or distance between the forsaids base, and the top of the saids Castles, Towres or Hills, &c. being measured (as it were) with a Plumb-line or string.

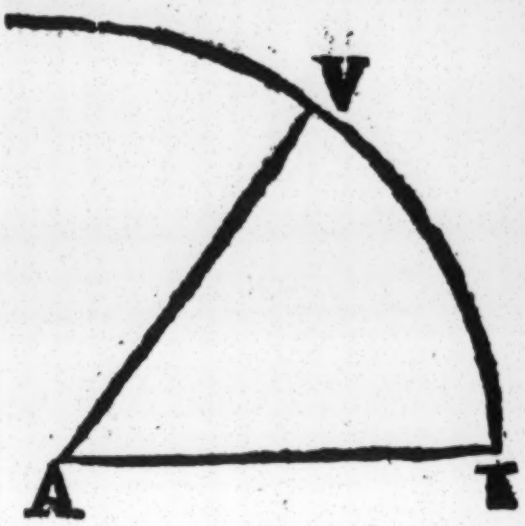
21. The *Hypothenusal* line, is a line ascending slopwayes from your eye, (or any part of the base) unto the very top of a Hill or Tower, &c.

22. Your *Stations*, is the place where you make your stand, when you observe with your Quadrant, &c. for finding the height of any place: But the stationary distances, is the distance between your two stations, or between one of your stations and the foot or base of the Tower, &c.

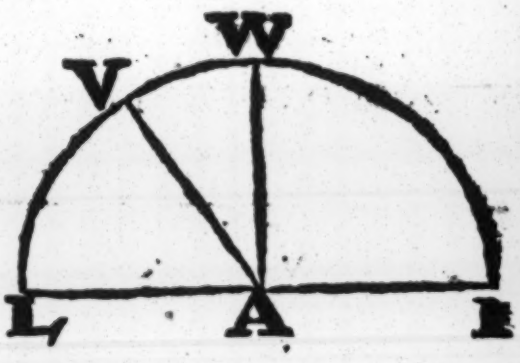
23. These *stationary* distances, must alwayes be exactly measured by a cord or string, that thereby you may know how many Paces, Els or Foots it is between the saids stations: And here note, that in finding out of heights and distances either with, or without Instrument, let alwayes your stationary distances be large, as occasion and conveniency will permit; for the greater the saids distance is, the truer will your work be; Yet not too great neither, only use a mean betwixt both, with discretion.

24. The

24. The *Quantity* or measure of an angle is the number of degrees contained in the arch of a circle, (described from the point of the same angle) and intercepted between the two sides of that angle: As for example, The measure of the angle V A I is the number of degrees contained in the arch V I, which subtendeth the Angle A. And in this example, the angle V A I contains 53 deg. 15 min.



25. The *Complement* of an arch lesse then a Quadrant, is so much as that arch wants of 90 degrees. As for example, suppose the arch L V to be 56 degrees, this substracted from (L W) 90 degrees, leaveth V W for the complement thereof, which is 34 degrees. But the complement of an arch lesse then a semicircle, is (in like manner) so much as that arch wants of a semicircle (or 180 degrees.) As for example, suppose the arch I W V to be 124 degrees, this substracted from (I W V L) 180 degrees, rests L V 56 degrees for the complement thereof.



26. Provide a pair of handsome Brasse Compasses, with a Rule made of Pear-tree, Boxwood, or Plain-tree, *&c.* let it be well plain'd and justly seem'd on both sides, and then you are in readinesse to perform the Geometrical conclusions following.

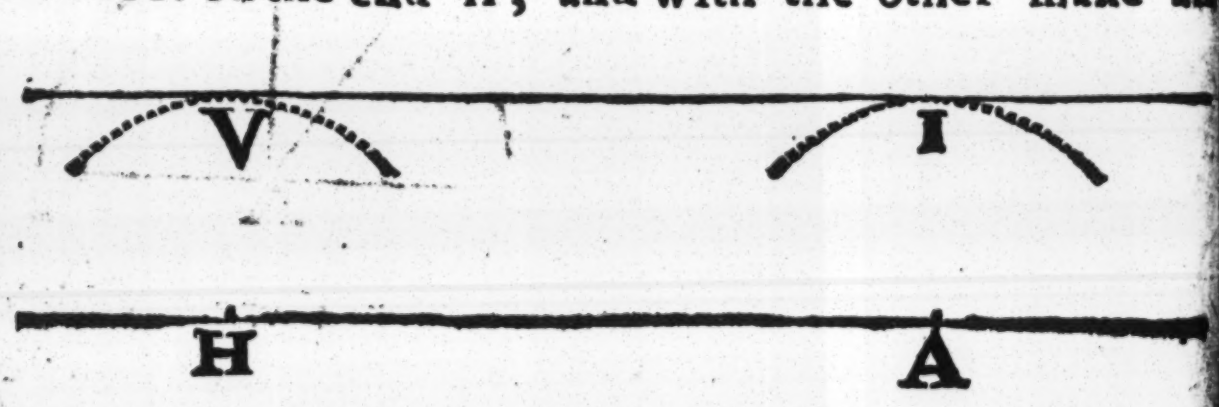
Lastly, Before you proceed, read over this Chapter

two or three times; for although I have been as plain therein as I can for your more eaſie conception, yet its your diligent and frequent reading that will onely bring you to the perfect knowledge thereof.

CHAP. II.

To draw a Parallel line, to any other line given, at any diſtance required.

SUppoſe the line given to be H A, unto which line it is required to draw a parallel line. To do this, open your Compaſſes to the diſtance required, and ſet one foot on the end H, and with the other make an



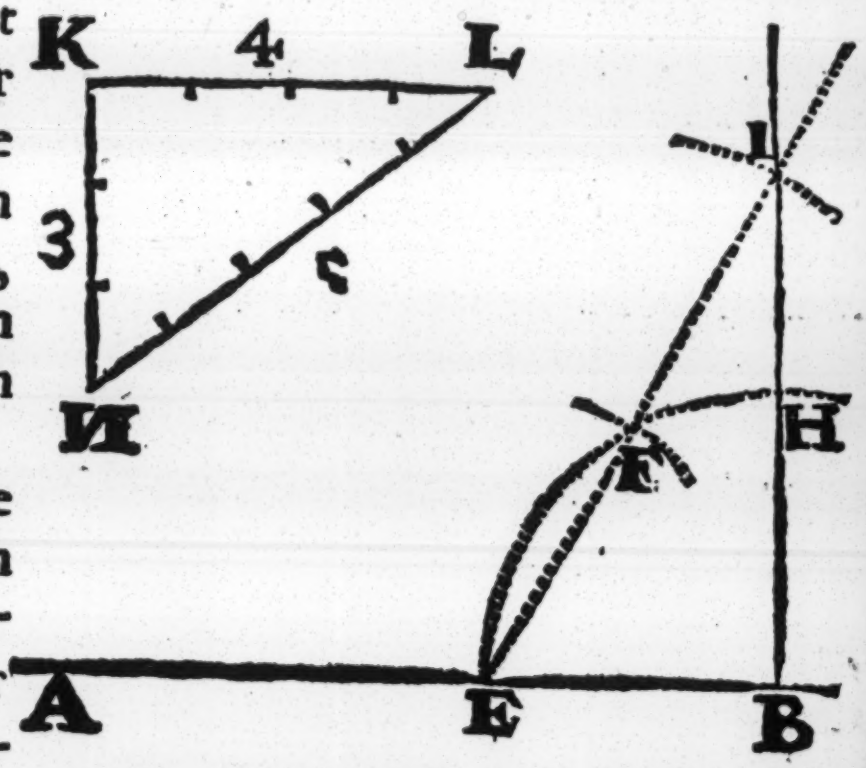
arch on that ſide of the given line, whereunto the parallel is to be drawn, as the arch line V, this done, draw the like arch (with the ſame wideneſſe of your Compaſſes) upon the end A, and by the convexity of theſe two arches, *viz.* V and I, draw the line V I, which ſhall be parallel to the given line H A, as was required.

CHAP.

CHAP. III.

To raiſe a Perpendicular line upon the end of a line given.

LEt the line given be A *B*, upon the end of which line as at B, the perpendicular is to be raiſed. Firſt, open your Compaſſes unto any convenient diſtance, as here I ſuppoſe to be the diſtance E B, then ſetting one foot of your Compaſſes in the point B, and with the other deſcribe the arch E F H, and with the ſame widneſs ſet one foot of your Compaſſes in the point E, and with the other foot, make a mark in the former arch E F as at F. Then ſetting one foot in F, with the ſame wideneſſe of your Compaſſes, deſcribe the arch I over the given point B. Laſtly, Lay your Rule upon the two points E and F, ſee where it croſeth the arch I, which will be at I, from which point I, to the given point B, draw the line I B, which ſhall be a perpendicular line raiſed from the end of the given line A B, as was required.



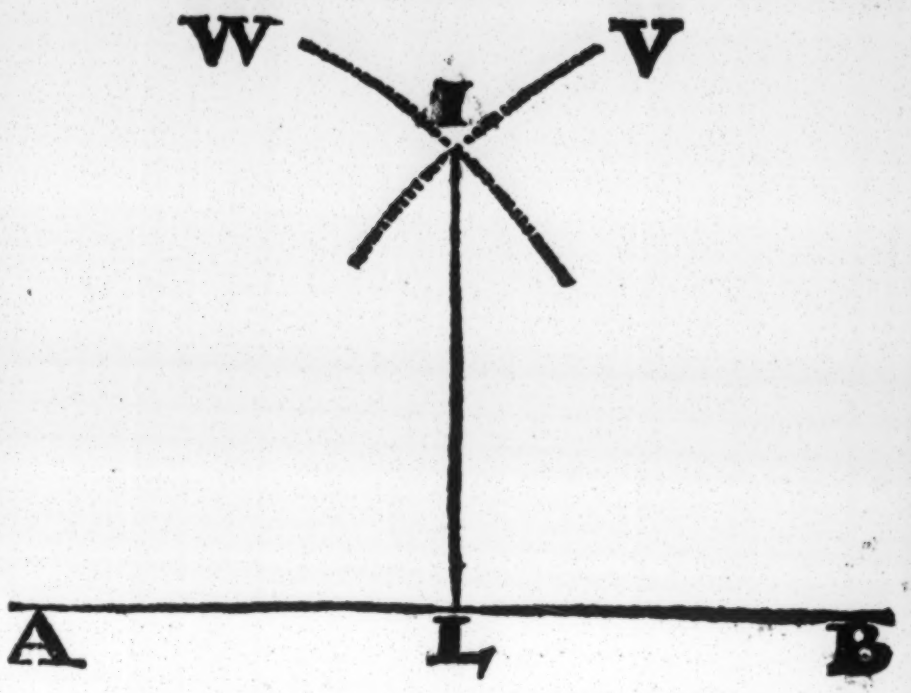
Otherwayes, to make a right angle, or to raiſe a perpendicular ſpeedily, do this: Draw the line N L, and opening your Compaſſes to any little diſtance or wideneſſe,

wideneſſe, begin at N, and number from thence five of thoſe equal parts, as here you ſee done, then opening your Compaſſes to three of theſe parts, ſet one foot in N, with the other draw an oculr arch towards K. Laſtly, Open your Compaſſes to four of thoſe parts, and ſetting one foot in L, with the other foot draw another oculr arch till it cut the former arch, which will be in the point K: Then draw the lines K L and K N, ſo ſhall the one of them be a perpendicular unto the other, and the angle N K L a right angle, that is to ſay, a Square; for either of theſe wayes may Maſſons and Wrights Squares be tried and juſted, becauſe theſe Geometrical projections which I have now ſhown you, is the very root from whence all (their) Squares have their beginning.

CHAP. IV.

To raiſe a Perpendicular line, from the middle of a line given.

SUppoſe the line given to be A B, and let L bee a point therein, whereon it is required to raiſe a perpendicular. Firſt therefore, Open your Compaſſes to any convenient diſtance, and ſo ſetting one foot in the point L, with the other foot make a mark on either ſide thereof, as A and B, which are equally diſtant from the point L: Then open your Compaſſes again to any convenient wider diſtance, and ſet one foot in the point A, and with the other deſcribe the arch W. In like manner, with the ſame wideneſs ſet one foot in the point B, and with the other draw the



the arch V, till it cut the arch W, in the point I, from which point I, to the point L, draw the line I L, which line is a perpendicular unto the given line A B, as was required.

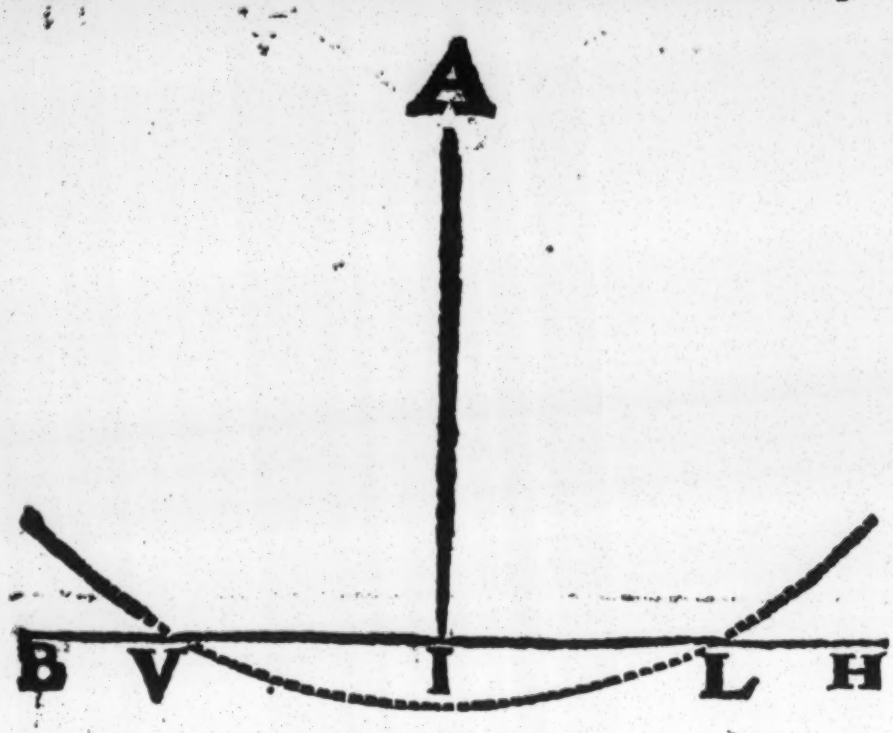
That excellent and useful Instrument which is frequently used both by Massons and Wrights, called the *Level*, hath its root and derivation from this Geometrical demonstration, and by this means may they be tryed, and justed, and corrected too, when necessity requires it.

CHAP. V.

To let a Perpendicular fall from a point assigned, unto the middle of a line given.

Suppose the line given whereon you would have a perpendicular line let fall, be the line B I H, and let the point assign'd be A, from whence you would have a perpendicular line let fall, upon the given line B I H. To do which: First, Set one foot of your Compasses in the point A, and opening your Compasses to any convenient distance, so that it be more then the distance

A I



A I, and de-ſcribe an arch of a circle ſo, that it may cut the given line B I H twice, that is at V and L: This done, de-vide the di-ſtance V L in-to two equal parts, the midſt is I, from which point I, to the aſ-ſign'd point A, draw the line A I, which is the perpendicular that was to be let fall from the aſſign'd point A, unto the middle of the given line B I H, as was required.

This concluſion is often in practice amongſt Maſ-ſons, Wrights, Painters, Gardiners and Mathemati-cians, who are frequently confin'd to a certain point, from whence a perpendicular muſt iſſue to ſome part of a line, which is oppoſite to the ſaids given point: which part, in the ſaids oppoſite line, is difficult and doubtful to obtain, until found out as I have here ſhewn you.

Thus I have ſhewn you the meaning of the moſt uſu-all (and frequently the moſt difficult) terms of Geo-metry, with the drawing of parallel lines, raiſing and letting fall, of perpendiculars from the end, or any part of a line, and from a point aſſign'd, to the end or middle of another line: which being well underſtood and practized, will not only be a ſufficient introducti-

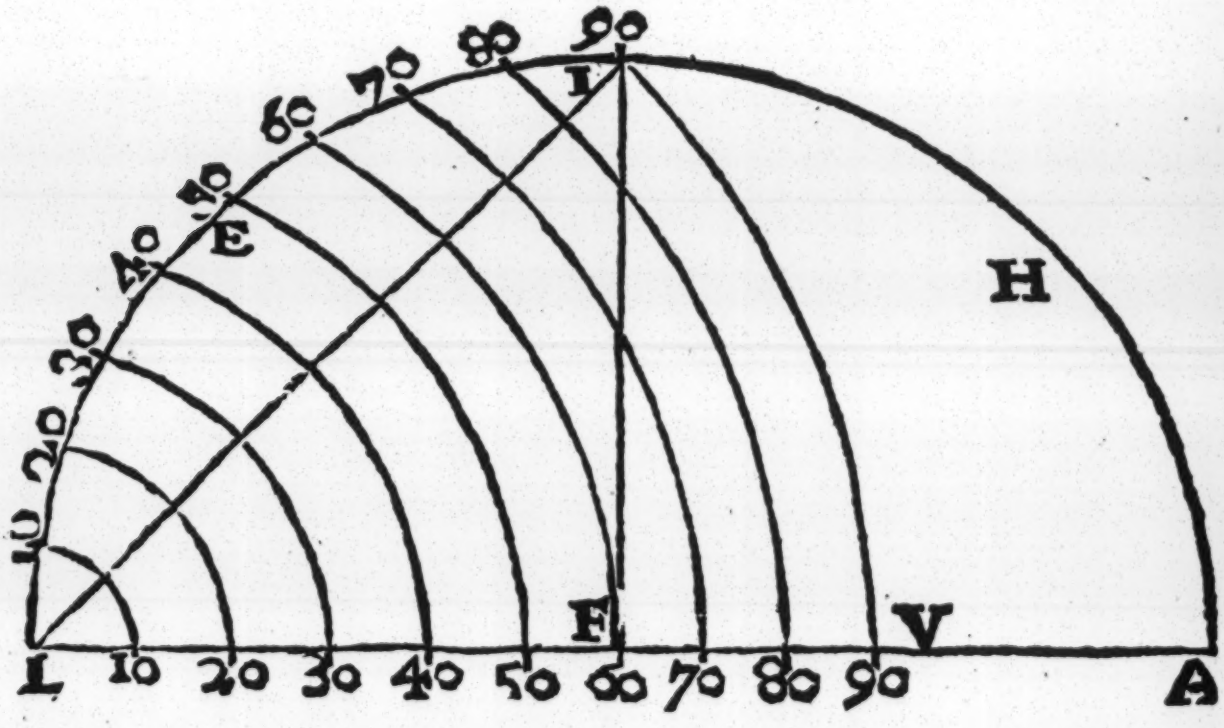
on

on to your further procedour into other Arts Mathematical, but alſo you will more eaſily conceive the reaſon and demonſtration of thoſe things which follow.

CHAP. VI.

How to make a line of Chords and equal parts.

FIrſt draw a ſtreight line, as L F A, then opening your Compaſſes to any convenient diſtance, upon the center F, deſcribe the ſemicircle L I A, which devided into two equal parts, or Quadrants, by the



point I, then deviding one of theſe Quadrants, as L E I into 90 equal parts or degrees, as here you ſee the Quadrant L E I.

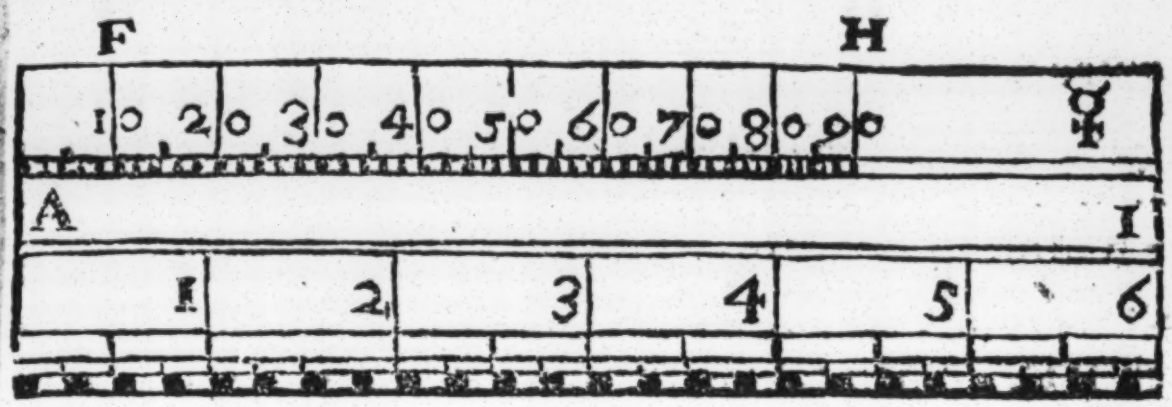
This done, ſet one foot of your Compaſſes into the point L, and extend the other to each degree of the Quadrant L E I, and theſe extents transfer into the

the line L F A, as you ſee here done. And this li L F A, ſo devided into 90 unequal parts, from the poi L, (and numbred with 10, 20, 30, 40, *&c.* unto 90, is called a line of Chords, which may be taken an placed on a Rule, as here you ſee is done. This chor line is in uſe to meaſure any part or arch of a circle not ſurmounting 90 degrees, the number of theſe de grees, *viz.* from 1 unto 60, is called the Radius o the line of Chords, upon which diſtance, all circles ar to be drawn, whereupon 60 of theſe degrees are th ſemidiameter of any circle, that is drawn upon tha Radius. As here you may perceive, that when you open your Compaſſes unto 60 degrees in the Quadrant L E I, and transfers it into the line L F A, that it will light upon the center F, whereby it doth plainly appear, that 60 of theſe degrees, are equal to the Semidiameter of the ſame circle, and conſequently is the Radius upon which all circles are drawn. Here note, that although *I* have made the Radius of the line o Chords L F here in this projection, not above two *Inches*: Yet when you project or make a line of chords for your own uſe, it were beſt to make the ſaids Radius *L* F, at leaſt four or five *Inches* long.

The line of equal parts, is onely a ſtreight line devided into *Inches*, each *Inch* being ſub-devided into 10, 12 or 16 equal parts, and numbred either with 1, 2, 3, *&c.* or with 10, 20, 30, *&c.* which line ſo devided equally, and numbred as aforeſaid, is called a line of equal parts, and may ſerve for ordinary meaſure.

Both

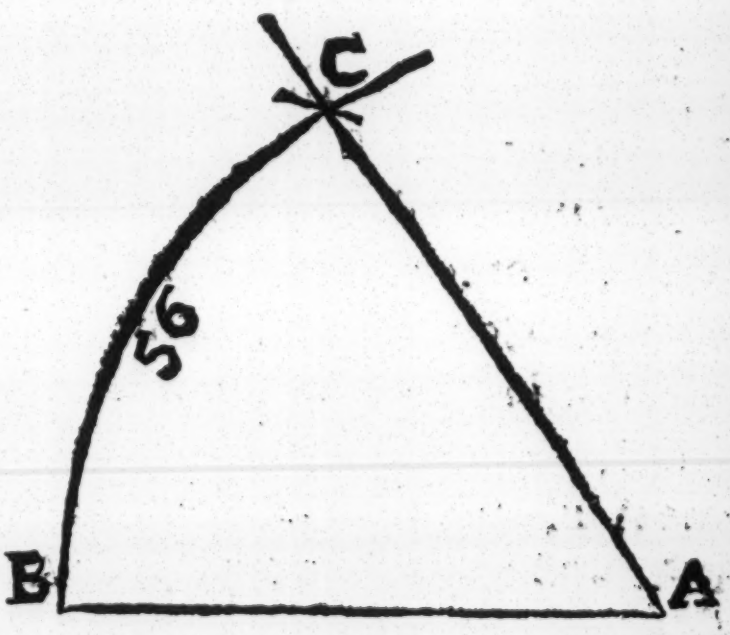
Both theſe lines, *viz.* of Chords and Equal Parts, may be placed upon a Rule, as here you ſee done, where the letters F H repreſents the line of Chords, and A I the line of Equal Parts.



CHAP. VII.

To make an Angle containing any Degrees aſſign'd: Or to meaſure the degrees of any Angle made.

YOu may make an Angle of any quantity ſpeedily with your Rule and Compaſſe, thus. Open your Compaſſes to the Radius of your line of Chords, and ſetting one foot thereof in the point A, with the other foot deſcribe the arch B C: Then draw the line A B, and ſo opening your Compaſſes to ſo many degres upon your line of Chords, as you would have your Angle



to

to contain, which here we ſhall ſuppoſe to be 56 degrees. With which diſtance, ſetting one foot in B, with the other make a mark in the arch B C, as at C: from which point C, draw the line C A, which ſhall make the angle B A C, containing 56 degrees, as was required.

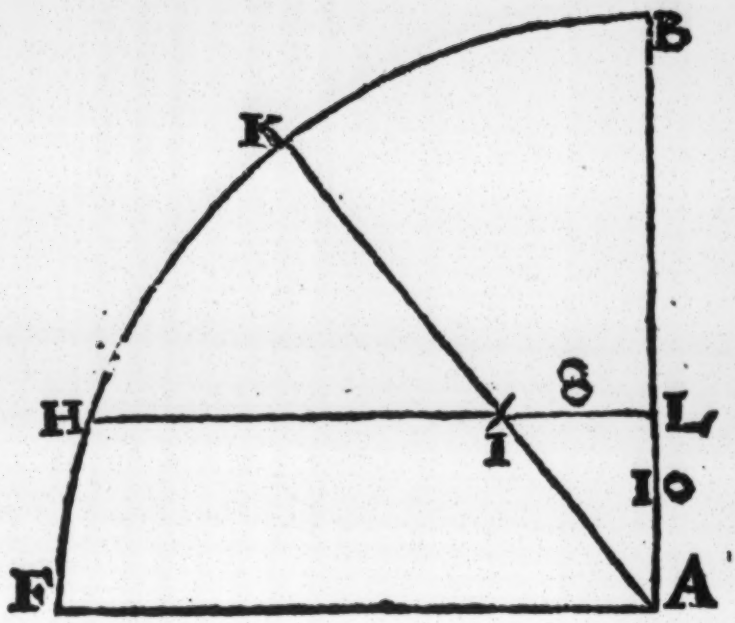
Now, when any Angle is made to find the degrees and minuts thereof. Firſt, Open your Compaſſes to the Radius of your line of Chords, and ſetting one foot thereof in the point A, with the other deſcribe the arch B C. Then taking the diſtance betwixt B and C, and apply it unto the line of Chords, and there it will ſhew you the number of degrees contain'd in that Angle, which here will be found to be 56 degrees, as was required.

CHAP. VIII.

To find the Altitude of the Sun, by the ſhaddow of a Staffe, or any other Gnomon.

FIrſt, draw the line A F, and ſo opening your Compaſſes to the Radius of your line of Chords (which is alwayes 60 degrees) ſetting one foot in the end A, with the other deſcribe the arch F K B: Then opening your Compaſſes unto the whole 90 degrees, with one foot in F, with the other make a mark in the arch F K B, in the point B, from which point B, draw the line A B, which ſhall be perpendicular unto the line A F, and make the Quadrant A F H K B.

Then



Then ſuppoſe the length of your Stafe, or Gnomon (yeelding ſhaddow) to be ten foot: Therefore take ten of your equal deviſions or parts, from your line of equal parts, and ſet from A to L, and ſo draw the line H L parallel to A F. Then ſuppoſe the length of the ſhaddow to be eight foot, therefore I take eight of the ſame equal parts, and ſets from L to I, by which point I, draw the line K I A, from the Center A, through the point I, until it cut the arch F K B, in the point K, ſo ſhall the arch F K, be the Altitude of the Sun deſired, which in this example will be 51 deg. 20 min. as was required. The Suns altitude may be found with more facility, with the Geometrical Quadrant, thus. Hold up your Quadrant to the Sun, the Thteed and Plummet having their free courſe, *&c.* See *Uranoſ. cap.* 26.

CHAP. IX.

Shewing the Latitude of the moſt Principall Cities, and Towns in Scotland, England, *and* Ireland.

BEfore we make any further progreſſe, I hold it neceſſary and expedient (for the readers more facile underſtanding of the ſequel) to demonſtrate; what the latitude of a place is: and therefore, briefly;

The

The latitude of a Countrey, City, Town, or place is an arch of the Meridian Circle, included between the Horizon and the Pole; or it is the distance betwee the Zenith of any Countrey, City, &c. and the Equinoctial.

The meaning whereof is this, look how many degrees and minuts the North Pole is raised above the Horizon (or levell) of any place: so much is the latitude thereof.

As for Example, in the following Table, over against the City of *London*, you see 51 32, *viz.* 51 degrees 32 minuts, that is to say: The latitude (or heighth of the North *Pole* above the Horizon) of *London* is 51 degrees 32 minuts.

In like manner, the latitude of *Edinburgh* is 56 deg. 4 min. The latitude of *Dublin* is 53 deg. 11 min. And the latitude of *Innerneſſe* is 58 deg. 55 min. as the Table demonſtrats. Thoſe that deſires to know the latitude of any place wherever they come, will finde the way to do it, in the 28 chap. of my *Uranoſcopia*, to which I refer them.

I have here given you a Table, which ſhews you the latitude of the moſt principal Cities and Towns, in great *Britain*, and *Ireland*: exactly rectified for the reſpective places therein contain'd: in which Cities or Towns, where it ſhall happen you to remain, you need not (unleſſe for correction or confirmation) trouble your ſelf to ſearch for the latitude thereof, but to take the ſame as it is here expreſt. But if you abide in a place which is not herein contain'd, then look what City or Town in the Table lyes neareſt to the place of your abode, and call the latitude of that City or Town, the latitude of your place. So that if

you

you were to make an Horizontal Sun-dyal, or to project an oblique Sphere, &c. to the saids place of your abode, you may do it (according as I have shewn you in the two following Chapters) for the latitude of that City or Town, which you find (in this Table) to be neareſt to the place of your reſidence which will occaſion little difference, or (at moſt) be an error altogether inſenſible.

The Latitude of

	deg.	min.		deg.	min.
S. *Andrews*	56	26	*Dundee*	56	34
Aberdeen	57	35	*Dunnoter*	57	20
Arbroth	56	49	*Derby*	53	06
Air	56	04	*Dublin*	53	11
Berwick	55	49	*Edinburgh*	56	04
Briſtol	51	32	*Elgin*	58	40
Bedford	52	18	*Falkirk*	56	04
Bruntiland	56	11	*Glaſgow*	56	03
Cambridge	52	17	*Hereford*	52	14
Coventry	52	30	*Halifax*	53	49
Colcheſter	52	08	*Hull*	53	50
Carlile	55	43	*Hadington*	56	00
Cowper of Fife	56	28	*Hamilton*	56	02
Clacmannan	56	11	*Irewin*	56	03
Culroſſe	56	11	*Innerneſſe*	58	55
Dumfermling	56	11	*Kelſo*	55	50
Dumfreis	55	50	*Kirkubright*	55	40
Dumbar	56	00	*London*	51	32
Dalkeith	56	00	*Leiceſter*	52	40
Dumbarton	56	03	*Lincolne*	53	15

Lanerk

The Latitude of

	deg.	min.		deg.	min.
Lanerk	56	00	*Roſſe*		
Leith	56	05	*Richmond*	54	26
Lithgow	56	04	*Stafford*	52	55
Mancheſter	53	24	*Stirling*	56	08
Muſſilburgh	56	00	*Thurſo*	60	00
Munroſſe	56	45	*Tain*	59	09
Notingham	53	03	*Tredah in* Irl.	53	38
New-wark	53	02	*Worceſter*	53	20
Norwich	52	44	*Warwick*	52	25
Newcaſtell	54	58	*Wincheſter*	51	10
Oxford	51	42	*Yarmouth*	52	45
Perth	56	31	*York*	54	00
Peter-head	58	35			

Here note, that all Cities and Towns which ly directly Eaſt and Weſt one of another, hath one and the ſame Latitude, but they differ in longitude. And all ſuch places which are ſcituate (directly) North or South one of another, have one and the ſame longitude and meridian, they differ onely in Latitude.

CHAP. X.

To project the Sphere in Plano for any Latitude.

THe knowledge of the various Circles, points, and lines, which are imagined in the Heavens, is very neceſſary and requiſite to moſt profeſſions, for to underſtand

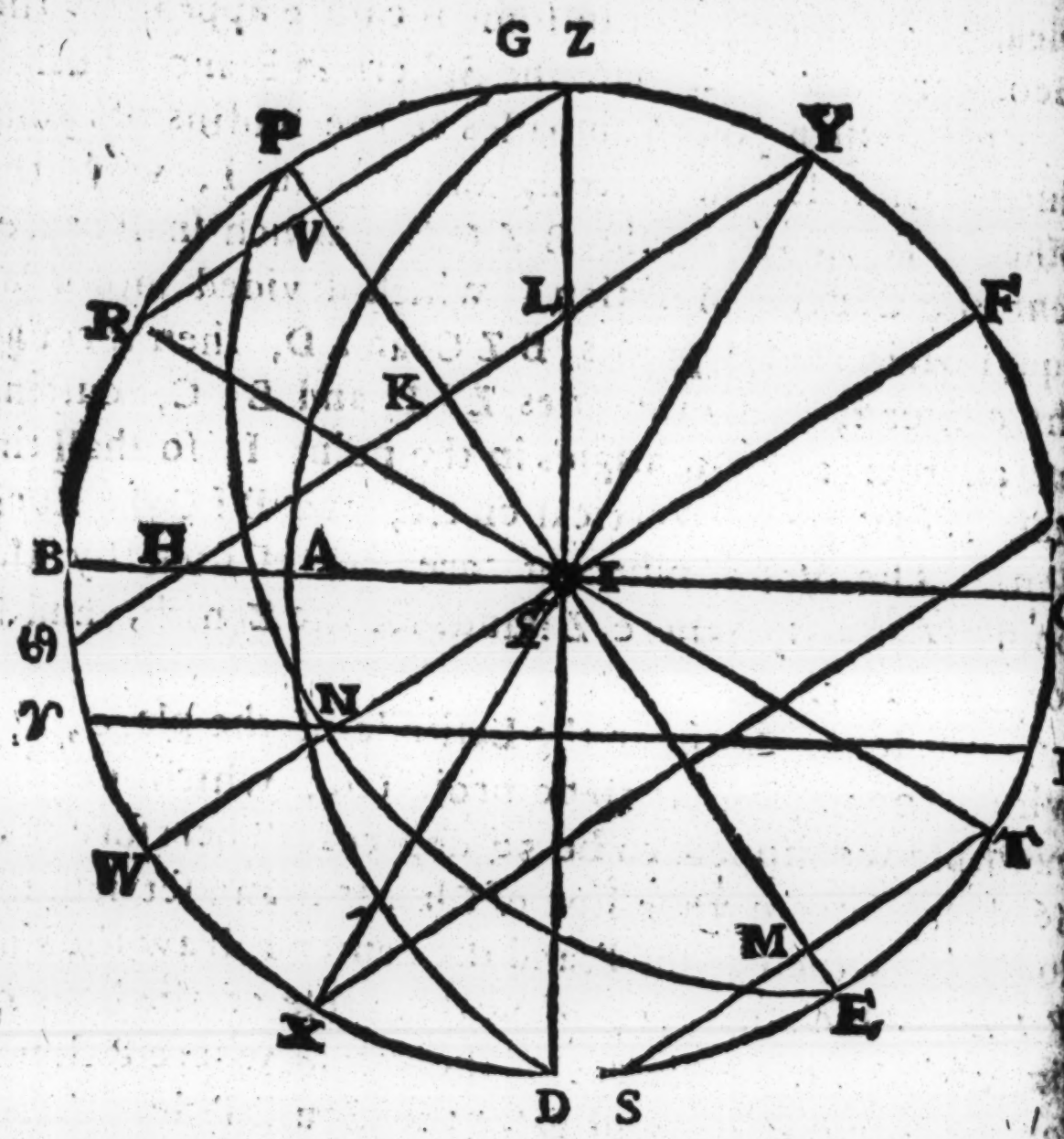
ſtand the Celeſtial motions, their right and oblique Aſcenſions and Deſcenſions, &c. is both profitable and pleaſant; which will in ſome meaſure appear, by the Geometrical Projection of the Sphere in Plano, thus.

Firſt, Open your Compaſſes to the Radius of your line of Chords, and ſetting one foot in I, with the other deſcribe the circle B Z C D, which ſhall repreſent the General Meridian; which devided into four equal parts in the points B Z C and D, then through the center I, draw the lines Z I D and B I C, cutting on another at right angles in the point I, ſo ſhall the line Z I D, be the Vertical circle, and B I C the Horizon. The Poles whereof are repreſented by the points Z and D, where Z ſtands for the Zenith, and D for the Nadir.

This done, conſider the Latitude of the place, for which your Sphere is to be projected, which in this example we ſuppoſe to be 56 degrees. Therefore take 56 degrees from your line of Chords, and ſet from B to P, by which point P, and the center I, draw the line *P I E*, which ſhall repreſent the circle of the hour of ſix, and alſo the Axletree of the world, where P ſtands for the North Pole, and E for the South Pole. Then take the ſaids 56 degrees, *viz.* P B, and ſet from Z to F, and ſo draw (through the center *I*) the line FIW, which ſhall repreſent the Æquator.

Then with your Compaſſes, take 23 deg. 31 min. (being the Suns greateſt declination) and ſet from *F* to Y, and from *F* to ♍ : and upon the oppoſite end of the Æquinoctial line, from W to ♋, and from W to X, by which points, Y ♋, and ♍ X, draw the lines Y L ♋, which ſhal repreſent the Tropick of *Cancer*, And ♍ X,

the Tropick of *Capricorn*, and the line ♈ I ♎, the Ecliptique.



Then take the ſaids 23 deg. 31 min, *viz.* the diſtance F Y, or F ♈, and ſet from the North Pole P, to G; and from P to R: and from the South Pole E, to T, and from E to S: and ſo draw the lines R V G, for the Artick Circle, and the line S M T for the Antartick Circle. This done, lay a Rule upon the points R and T, and ſo draw the line *R I T*, which ſhall repreſent the Axis of the Zodiack, the Poles whereof are R and T. This done, take 18 degrees from your line of

Chords

Chords, and ſet from the Horizontal line B D C, from B to ♈, and from C to ♊, and draw the line ♈ N ♊, which is the line of Twilight, or day Breaking.

The hour Circles are (repreſented by the Arch P N E, and) drawn through every 15 degree of the Æquator, cutting one another in the Poles of the World. But the Azimuth Circles, are (repreſented by the arch Z A D and) drawn through every 11 deg. 15 min. of the Horizon at right Angles, cutting one another in the Poles of the Horizon, *viz.* the Zenith and Nadir.

The hour Circles, Azimuths, together with the 12 Sighs, may be placed upon their reſpective lines, by help of a line of Sin's fitted for the Radius of your line of Chords, which for brevities ſake *I* have now omitted. *I* ſhall only add an example of this projection, and ſo conclude this Chapter.

Suppoſe the Sun in the Tropick of *Cancer* (which is, when our day is at the longeſt) at Y, then his Meridian Altitude is repreſented by Y C: His Depreſſion at midnight by B ☋, his Semidiurnal arch by H Y, his Seminocturnal arch by ☋ H, his Altitude in the Vertical Circle by I L, his Declination by *I K*, his Amplitude by H *I*, and his Aſcenſional difference by the line K H.

CHAP. XI.

To draw a Horizontal Dyall for any Latitude, or place of the Earth whatſoever.

AMongſt other defects in the Countrey, this is not the leaſt, *viz.* the want of Sun-dyals; for travel

where you pleaſe, and upon what Road ſoever, wher
you ſhall ſee a Sun-dyal fixt at, or upon any place, yo
ſhall ſee thouſands lacking them. You muſt eithe
take their common and ruſtick gueſſe of the time
the day (which they gather from their looking up
the Sun) or elſe go without.

Now from whence comes this defect amongſt them
I do really think, that it doth not ariſe from any co
tempt or hatred which they have, to Arts and Scienc
Mathematical: But rather for want of a fit inductio
and incitement to ſome convenient ſubject of theſe Ar
and *Sciences*: which (being made naked from all a
ſtruſe and oculr ſcrutinies) ſhould be ſo levelled,
that it may be parallel with, and comprehenſive t
their capacities.

I waited (I confeſſe) very long to ſee if ſome mo
able then my ſelf would redreſſe this evil, for the fu
ture; but finding none to appear, though we hav
amongſt us, very many, more richly qualified for thi
effect then my ſelf: I was conſtrained out of mee
love and pity, to become the Countrey-mans Tuto
and to expoſe my ſelf to publike view on their behal
And therefore, he, or they, that would draw a Sun-di
(I mean an Horizontal or Level-dial) exactly, fo
whatſoever latitude or place of the earth, let the fol
lowing precepts be duely obſerved.

But before we proceed, I think it not amiſs, firſt,
to ſhew you this General Maxime in the Art of dyal
ing, *viz. That the Stil's of all Dyals muſt neceſſarily
point to one of the two Poles of the World.* From hence
it followes, that a Horizontal Dial drawn for one lati
tude or place of the World, will not exactly ſerve for
an Horizontal Dial to another latitude or place of the
World

World, that is to say, that a Dial made for *London*, will not serve exactly at *Edinburgh*. *& è Contra*, one made for *Edinburgh* will not serve at *London*. The reason is palpably manifest, because (according to the foresaids Maxime) the stile of that Dial which is made for *London*, being set up at *Edinburgh*, will not exactly point to the North Pole of the world, but will point 4. deg. 32 min. below the same (for so much is the difference of Latitudes betwixt *London* and *Edinburgh*, *London* being 51 deg. 32 min. and *Edinburgh* 56 deg. 4 min.) And proportionably as the Latitudes of places differ, so will the Dials made for those places differ. But if there be no difference of Latitudes, the Dyal that is made for one place, City or Town, will serve for any other place, City or Town, though never so remote one from another. The reason of this is also clear; because, when there is no difference of Latitudes, then these Cities or Towns (though never so far distant one from another) are both in one and the same Parallel to, (or from) the Equinoctial, and so have both one Latitude or Elevation of the Pole. That is to say, in more plain terms. An Horizontal Dyal drawn for the Latitude of *Edinburgh*, will serve any other place (though never so remote asunder) that lyes exactly East or West of *Edinburgh*, without any difference at all. These things being thus necessarily premissed, I come next to practice.

An Horizontall dyal is that which is parallel to the Horizontall Circle of the Sphere, and therefore to draw the hour lines, first open your Compasse to the Radius of your line of Chords, and with this distance, setting one foot in the Center K, with the other describe the Circle E S W N, and upon the saids point K,

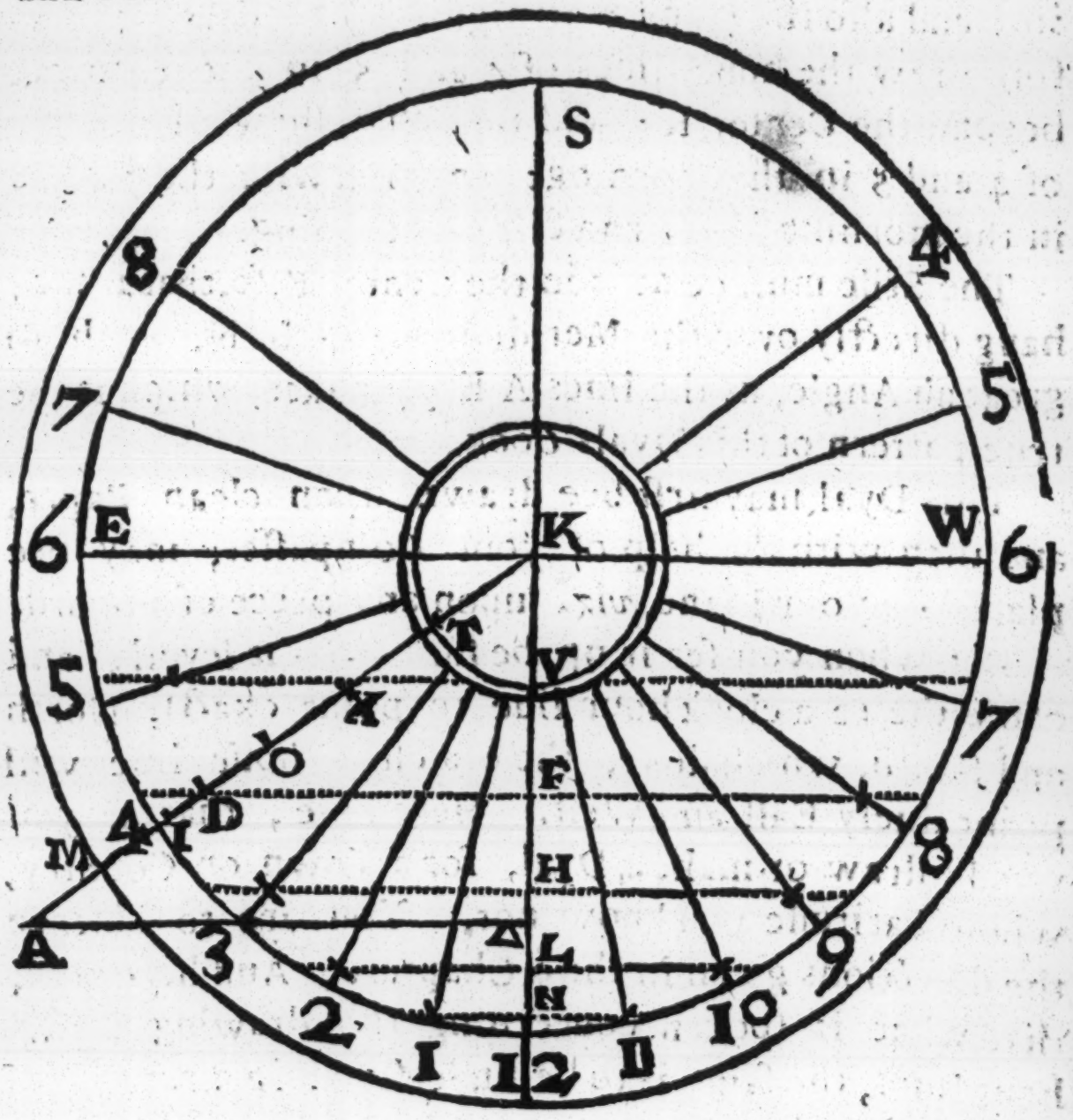
draw

draw another concentrick *Circle*, a little without the former, for to contain the figures of the hour-lines. Then divide the Circle E S W N, into four equal parts, and through the center K, draw the lines E K W and S K N; cutting one another at right Angles in the Center K. So shall the line E K W, be the six a clock hour line; both for morning and evening. And the line S K N, the Meridian; or 12 a clock hour line.

Then take the latitude of the place, which here (in this example) we will suppose to bee 56 degrees; therefore take 56 degrees from your line of *Chords*, and set from N to I, and draw the line K I A. Then from the point A, let fall the *Perpendicular* line A △, till it cut the 12 a clock hour line S K N, in the point △. So shall the Triangle △ K A, be the true patern of this Dyals *Cock*; which may be made of a plate of thin *Brasse*, Iron, or other material substance as you think most convenient.

This done, devide the semicircle E N W into 12 equal parts. So have you in each Quadrant five points, by which you may draw the five *Chord* lines, *viz.* V F H I, and N. Parallel to the six a clock hour line, as here you see done. Then take one half of the *Chord* line N, with your *Compasses*; and this distance set in the line of the stile, *viz.* from K to T, from which point T, take the nearest extent unto the Meridian (or 12 a clock hour line) and with this distance, setting one foot in the point N, with the other make a mark, on each side of the Meridian, in the same *Chord* line N. Through which points from the *Center* K, you shall draw the hour lines of 1 and 11. In like manner, take one half of the *Chord* line L, and set from K to X, from which point X, take the nearest extent unto the Me-

ridian; and with this distance, setting one foot in the point L, with the other, make a mark, on each side of the Meridian, in the saids Chord line L, through which points, and the Center K, draw the hour lines of 2, and 10.



In like manner, take the half of the Chord line H, and place it in the line of the Stile from K to O, from which point O, take the neareſt extent unto the Meridian, and with this diſtance, ſetting one foot in the point H, with the other make a mark, one each ſide of the Meridian, in the ſaids Chord line H, through which

points,

points, draw the hour lines of 3 and 9. And thus you may proceed to the drawing of the reſt of the hour lines, as the figure demonſtrats, ſeeing the work is ſooner done then ſpoken.

And whereas in *Summer*, the 4 and 5 in the morning, and alſo the 7 and 8 at night, is neceſſary: therefore draw the hour lines of 4 and 5 in the evening, beyond the *Center* K; and they ſhall ſhew the hours of 4 and 5 in the morning: and likewiſe the 7 and 8 in the morning, for 7 and 8 in the evening.

The Stile muſt be fix't in the *Center* K, ſo, that it may hang directly over the Meridian line S K N, with ſo great an Angle, as the lines A K △ makes, which is the true pattern of this Dyals *Cock*.

This Dyal may firſt bee drawn upon clean *Paper*, and then with the help of your *Compaſſes*, may bee placed on your Plane, *viz.* upon any peece of a boord.

But when you ſet it up, be ſure to ſet it levell; and cauſe the 12 a clock hour line to point exactly North and South, which done, the 6 a clock hour line will point duely Eaſt and Weſt. Here note, that if you would draw or make a Dyal, for a Town or Country, whoſe Latitude you know not. You are to obſerve the directions given in the 9 Chapter. And here note, that what is ſpoken concerning the drawing of the hour lines, the ſame is to be underſtood in drawing of the halves and quarters.

CHAP.

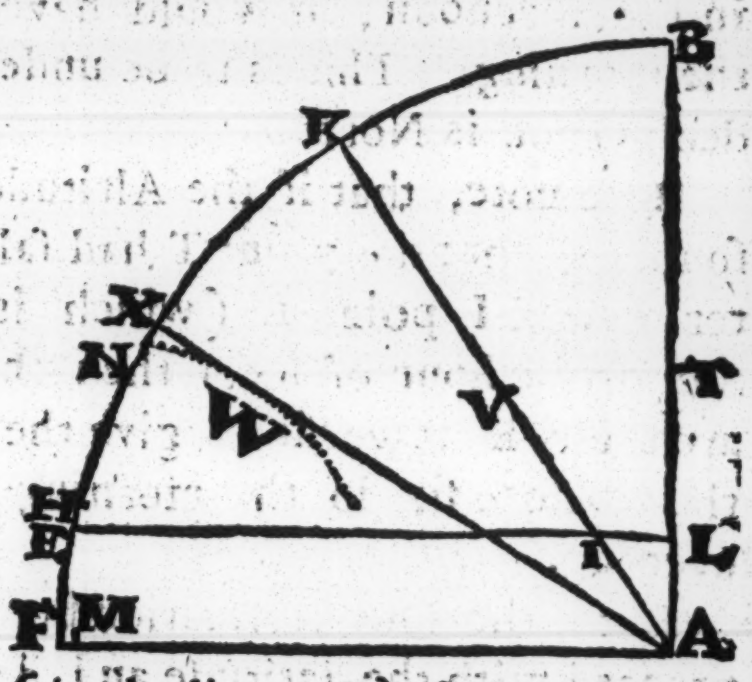
CHAP. XII.

To finde the hour and minut of the day, in any part of the World, Geometrically *without Instrument.*

WHo ever would do this exactly, must first, necessarily know

The { Latitude of the place / Altitude of the Sun / Suns Declination. } according to the { IX / VIII / XVII } Chap.

All which, will be sooner done then spoken. Now to find the time of the day thereby, in whatsoever part of the world you be in. First, Draw the Quadrant A F H K B, as is taught in the eighth Chapter, then suppose the Latitude of the place to be 56 degrees, take it from your line of Chords, and place it from F to K, and so draw the line A K. Then set the Suns Declination (which here we suppose to be 13 degrees, 14 minuts) from F to H, from which point H, take the neerest extent with your Compasses unto the line A F, and set this distance (in the line A K) from A to I, through which point I, draw the line E I L, parallel to A F. Then from the aforesaid point H, take the neerest



neereſt extent unto the line A L B, and ſet it from A t
M, in the line A F. Then ſuppoſe the Suns Altitud
(obſerved in the afternoon) to be 27 deg. 30 min
Place it from F to N, from which point N, take th
ſhorteſt extent unto the line A F, and this diſtance ſe
in the line AB, from A to T, then take the diſtance L T
and ſet one foot of your Compaſſes in the line A K, ſ
as the other foot may but juſt touch the line A *B*, an
where the fixed foot ſhall reſt, make a mark as at V
Then with the diſtance A V, ſet one foot of your *Com*-
paſſes in the point M, and with the other deſcribe th
arch W, by whoſe convexity and the *Center* A, draw
the line A X, ſo ſhall the arch F X, be the quantity o
time from the hour of ſix, and B X the time of the da
from Noon. Which arch B X being taken with you
Compaſſes, and applied to the line of *Chords*, will b
60 degrees, that is, (by allowing 15 degrees to on
hour) four hours in the afternoon; but if it had bee
in the forenoon, it would have been eight a clock i
the morning. This is to be underſtood when the Sun
declination is North.

Here note, that if the Altitude of the Sun had bee
ſo ſmall, that the point T had fallen between the Cen-
ter A and I point L (which is the Altitude of th
Sun at the hour of ſix) then ſhould that part of th
arch F N K towards F, give the quantity of time, ei-
ther before ſix in the morning, or after ſix in the
evening.

But if the Suns declination be *Southwards*, you mu
proceed with the latitude and declination of the Sun,
in drawing the lines, and taking the extents, as is al-
ready ſhewed; but in the Suns *Altitude*, the diſtance
between the point N, and the line A F, muſt be ſet
from

from L to T, and ſo (in ſtead of L T) you muſt take the diſtance A T, and then proceed as before: for there is no other difference at all, then what *I* have ſhewed. Thus will ye finde the hour and minut of the day both in Winter and Summer, by obſerving the premiſſes.

CHAP. XIII.

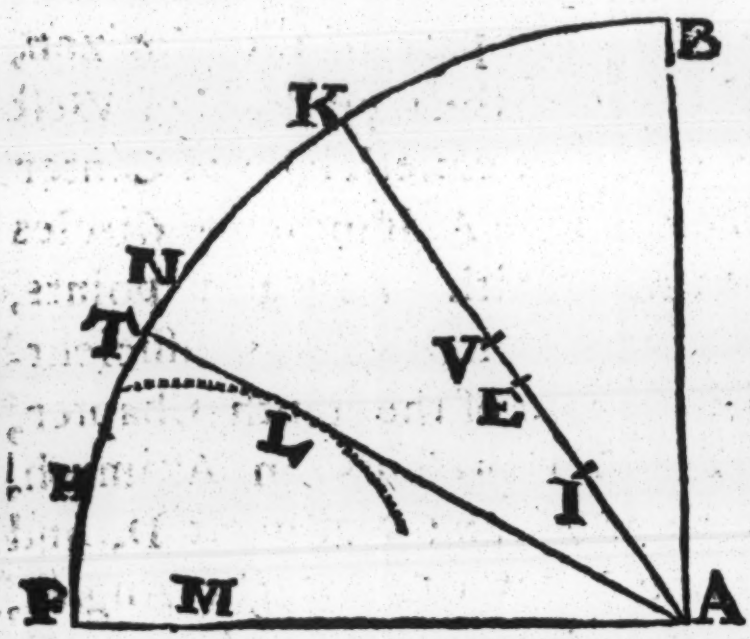
To finde the Suns Azimuth Geometrically.

THe Azimuth of the Sun, is a part of the Horizon, which is contain'd betwixt the true Eaſt or Weſt points, and that Azimuth which paſſeth by the Center of the Sun to the Horizon. Theſe Azimuths are Circles which meet together in the Zenith and Nadir points, and croſſe the Horizon at right Angles, as is ſufficiently demonſtrated in the *Sphere* of the tenth Chapter, where the ſemicircle Z A D repreſents an Azimuth, meeting with the Zenith at Z, and Nadir at D, and croſſes the Horizontal line B H A I C at right Angles, in the point A. The uſe of theſe Azimuths are diverſe, but in this Chapter, it is intended only to finde the point of the Compaſſe that the *Sun* is on at any hour and minut of the day: that is to ſay, to know how many degrees and minuts the *Sun* is diſtant from the true points of Eaſt or Weſt, towards the North and South, at any time of the day. Which you may find at any time by obſerving the directions following; which differs not much in operation, from finding the hour of the day: and therefore, knowing the *Latitude* of the place, the declination and altitude of the Sun

according

according as is before ſhewed: the Suns Azimuth will be found eaſily, artificially, and ſpeedily thus.

Firſt, deſcribe the Quadrant A F K B, as before; then with your Compaſſes ſet the Latitude of the place (which here we ſuppoſe to be 56 deg) from F to K, and draw the line A K; then ſuppoſing the Suns declination North-wards, to be 14 deg. 45 min. take it alſo from your line of Chords, and ſet from F to H, from which point H, take the neareſt extent unto the line A F, and with this diſtance, ſetting one foot of your Compaſſes in the line A K, ſo as the other may but touch the line A F, make the mark I, in the ſaids line A K. This done, ſuppoſe the Suns altitude obſerved in the forenoon to be 36 deg. 45 min. Therefore with your Compaſſes, take it from your line of Chords, and ſet it from F to N, from which point N, take the neareſt extent unto the line A B, and place this diſtance from A to M.



Then from the ſaids point N, take the neareſt extent unto the line A F, and ſet it from A to V (in the line A K) then take the diſtance I V betwixt your compaſſes, and fix one foot in the line A K, ſo as the other may but touch the line A B, and the fixed foot will reſt in the point E, from which point E, take the neareſt extent unto the line A F, with which diſtance ſet one foot of your Compaſſes in the point M, and with the other deſcribe the arch L, by whoſe convexi-

tie

tie, and the Center A, draw the line A L T: so shall the arch F T, bee the Suns Azimuth from the East or West, and the arch B T, his Azimuth from the South, which in this example (being taken with your Compasses, and applyed to the line of Chords) is 57 deg. 26 min. and from the East, 32 deg. 34 min. as was required.

Here note, that if the Sun had been so low that the point E, had fallen between the Center A, and the point I, then should the arch B T, have shewed the Suns Azimuth from the North; this is only when the Sun hath North declination.

But if the Suns declination bee South-wards, you must proceed with your Latitude and Declination, placeing them respectively as is before shewed. Only when you have taken the neareſt extent from H, (the Suns declination) to the line A F, and setting one foot in the line A K: so, as the other may but touch the line A B (in stead of A F) your mark is I. Then proceed with placeing the Suns altitude as before at N, from which point N, you must take the neareſt extents unto the line A B, (setting it from A to M) and A F, which distance or extent (from N to A F) must not be set from A to V (in the line A K) as before, but you must (with the saids distance) set one foot in the line A K, so as the other may but touch the line A B, and the fixed foot of your Compasses will rest at V, from which point V, take the neareſt extent unto the line A F, and place it from I to E. Lastly, take the distance A E, and setting one foot of your Compasses in the point M, describe the arch L, by whose Convexity, &c. as before. Thus you will finde the Suns Azimuth at any time of the year, in any part of the world,

world, moſt exactly and ſpeedily, and although the precepts here given, ſeem many, yet the work is (as will be after three or four tryals) ſooner done than ſpoken.

CHAP. XIV.

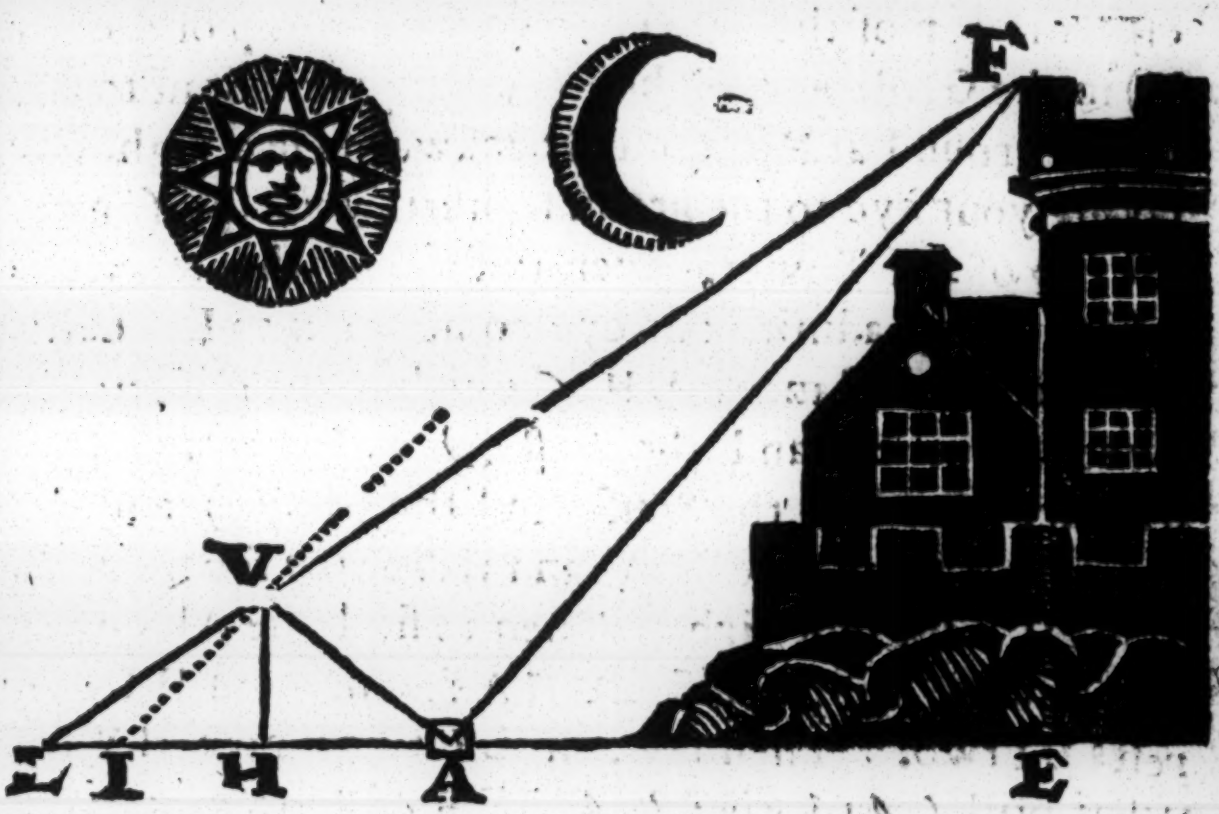
How to finde the true (Perpendicular) heighth of a Hill, Caſtle, or Tower, that is acceſſible, or inacceſſible, without any Inſtrument.

THis may be performed, either by help of a looking glaſſe, or elſe by a little clear water in a diſh; in my own practice, when *I* have been abroad in the fields, and having no Inſtrument by me, *I* have ſatisfied myſelf (and Students) ſometimes either of the wayes, and ſometimes both wayes, yet without the leaſt error alwayes.

Therefore, admit F were the top of a Tower, whoſe heighth above the ground at E, were required, and that the ſaids Tower E F, were acceſſible (*viz.* that I might approach (from A) to the baſe thereof at E, without any impediment of hills, rocks, walls, or ditches, &c.) Then to finde the true altitude thereof, place your looking-glaſſe, or diſh of water level on the ground at A, then (with your body upright, and your eye fixed on the glaſſe) go backwards in a right line untill you ſee the top of the Tower F, in the glaſſe at A, at which time ſuppoſe you go back to H; this done, meaſure the heighth of your eye from the ground, which ſuppoſe to bee ſix foot, likewiſe meaſure the

diſtances

diſtances between your ſtation H, and the glaſſe A, and alſo between the ſaids glaſſe A, and the baſe E, which done, ſuppoſe H A 9 foot, and A E 30 foot, then ſay, if A H 9 foot, give H V 6 foot, what ſhall A E 30 foot give? Multiply and divide, and the anſwer will be 20 foot, for the true altitude of the Tower E F, as was required.



But if the place (whoſe heighth is required) be inacceſſible, then there muſt be uſed another manner of Operation (not much differing from the former) to obtain the true heighth thereof, which is thus performed.

Admit F to be a Tower, built upon a Rock, unto the Baſe of which Tower there is (naturally) no acceſſe, becauſe of the ſaids Rock, whereon the Tower ſtands: And ſometimes (in War eſpecially) a Tower or Caſtle may have (no material or natural impediments to keep you from its Baſis, but) an accidental occaſio-

occaſional, or hazardous hinderance, by reaſon of the Enemies ſhot, from the ſaids Caſtle. Admit alſo you place your Glaſs on the ground, laying the ſame levell as you can, at A. This done, take a Staffe of 6 or 7 foot high, as H V, and ſo holding the ſaid Staffe upright from the ground, with your eye upon the top thereof at V, ſtill go backwards, untill you eſpy the top of the Tower F, (over the top of the Staffe V) in the Glaſſe at A. Then (cauſing your Staff to ſtick in the ground at H) go ſtill backwards in a right line laying your eye to the ground, until you eſpy (again) the top of the Tower, over the top of the Staffe, at which time, admit your eye come back to L. Laſtly Meaſure the diſtances L H (which is the diſtance between your eye and the Staffe,) and alſo H A (the diſtance between the Staffe and the Glaſſe,) and ſuppoſing L H to be nine foot, and H A ſeven foot, and the Staffe H V ſix foot high. Then to find the Altitude of the Tower, E F, Subſtract H A ſeven, from H L nine reſts L I two. Then ſay, if L I two, give H V ſix. What will *L A* 16 give? *Anſ.* E F 48 foot. —— That is to ſay, in more plain terms: The diſtance from the Glaſs A to the Staffe H, is ſeven foot, and from the ſaids Staffe A, to your eye at *L* nine foot, the ſum of both is ſixteen, and the difference is two, which known

As the difference L *I* two, is to the heighth of the Staffe H V ſix foot, ſo is the ſum *L A* ſixteen, to the required height E F 48 foot.

The reaſon of this Operation, is, That the Triangle A H V, is of one and the ſame proportion with F E A. And the Triangle V H *L* is as F E L: Therefore when we have made V H A equal to V H *L*, then is V I L of the ſame proportion with F A L, becauſe I V is pa-

ralle

rallel to A F. So that as L I (two) is to H V (six) So is L A (sixteen) to E F (fourty eight) the heighth of the Tower required.

CHAP. XV.

Shewing how to find the exact length, or distance to any mark or object, that's visible on the Land, be it never so far; and that without Instrument.

ALthough there be many wayes by which I might shew you the Resolution of this Question; yet for the young Student of *Geometry*, that he may the more speedily, and with the greater facility, comprehend the same: I shall make choice of that, which I know to be most familiar and easie, even such a way, as I my self (with my Domesticks) have most frequently practized; which if you follow, you shall (to admiration) find the saids length or distance from your station, to the mark or object, most infallibly, although the saids object, should be as far from your station, as the eye can see upon the Land. To do which,

You must have four Staves, (it's no matter whither they be all of on length or not, provided they be streight) I have oft enough performed the same (playing upon *Leith* links) with four Goff-clubs. Amongst an Army or Company of men, there is nothing better then four Halberds or Pikes, or four (Musketiers) Ramming-rods, &c. take any of these four, which opportunity

portunity best offers, and so let's go forth into the Fields.

And there,

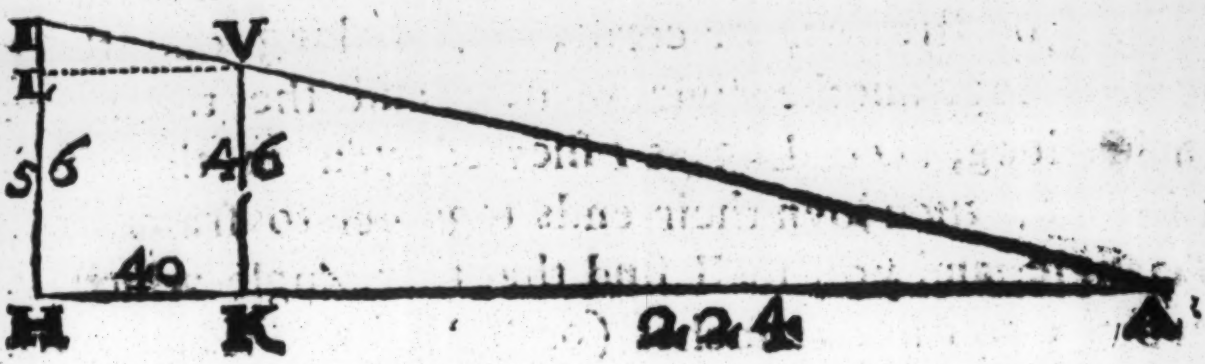
Suppose A to be a Fort or Bulwark, whose distance from our standing (at K, or H) is required. First therefore, thrust down one of your staffes at K, from which staff K, you must go exactly Square-wayes, (or as near to a Square as possibly you can) from the line K A, either to the right hand, or to the left hand, (according as the ground will permit) about 200 or 300 foot, (the more the better, if your object bee far off) as from K to V; and at V, set up the second staff.

Then come to your first staff at K, and go back from it, in a streight line, three or four hundred foot (more or lesse, at your pleasure, according to the vicinity of the object,) as from K to H, and at H set up your third staff; which you must so set, as that the first staff at K, and the object at A, may appear both in one streight line with the third staff at H, by the judgement of your eye.

This done, go side-wayes from H, upon a Square Angle (as you did before from K to V) untill your second staff at V, appear in a streight line from the object A, and your fourth staff at I, which being done, measure how many yards, ells, or foots, is between your first staff (at K) and the second (at V) and call that your first distance. And likewise between the said first staff (K) and the third (at H,) name it your second distance. Lastly, measure the distance between your third staff (at H) and fourth (at I,) which shall be your third distance, from which, substract the first distance, and the remainer is the deviſor, or first number in the Golden rule. Then say, if the remainer

give

give the ſecond diſtance, what ſhall the third diſtance give? Multiply and divide, and the Quotient will be the true and exact diſtance of the object at A, from your third ſtaff at H, as was required.



Example, in this Diagram ſuppoſe A to be the mark or object, whoſe diſtance is required. And let K bee your firſt ſtaff, V your ſecond, (being carried Square off from K) and H your third, and I your fourth ſtaff. Now meaſuring between V and K, ſuppoſe you finde it 46 ells (or foots, if you pleaſe to make it ſo) and between K and H 40, and laſtly, between H and I, 56.

Then if you ſubſtract, the firſt diſtance K V 46, from the third Diſtance H I 56: reſts L I 10, your Deviſor. Now, becauſe L V is equal (and parallel) to H K, both being 40. Therefore you may ſay, If the remainder I L 10, give the ſecond diſtance L V (which is equal, as I ſaid before, to H K) 40; what ſhall the third diſtance I H 56 give? *Anſwer*, H A 224 ells, and ſo much is the diſtance of the ſaids Fort at A, from the Staffe at H, as was required.

For let your object be never ſo far, if your eye can but perfectly perceive it: and placeing your Staffes, according as is before ſhewed, you ſhall ever have the required diſtance, only by the former Analogy or Proportion,

portion, *viz.* as I L is to L V, ſo is I H, to H A.

But becauſe this concluſion is performed without Inſtrument, and a *Square* motion ſide-wayes is required. Therefore *I* will hear ſhew you how to make a juſt *Square* upon the ſuddain. Take three ſhort ſtickes or ſtrawes, or cords, &c. making one three inches long, another four inches, and the third five inches long, according as *I* ſhewed you in the third Chapter: then joyn their ends together to frame your *Triangle*, and you ſhall find that that *Angle* which is oppoſite to the five inches (or longeſt ſide) is a Square or right Angle, which *Angle* firſt placed at K, and after at H, ſtill directing the ſtick of four inch long to the mark at A, the other ſtick of three inch long will direct you to V and I. Thus, obſerving the premiſſes, you may moſt exactly meaſure and finde out the diſtance of any place from your *Station*, as exactly (nay more) then if you meaſured the ſame with a cord or chain.

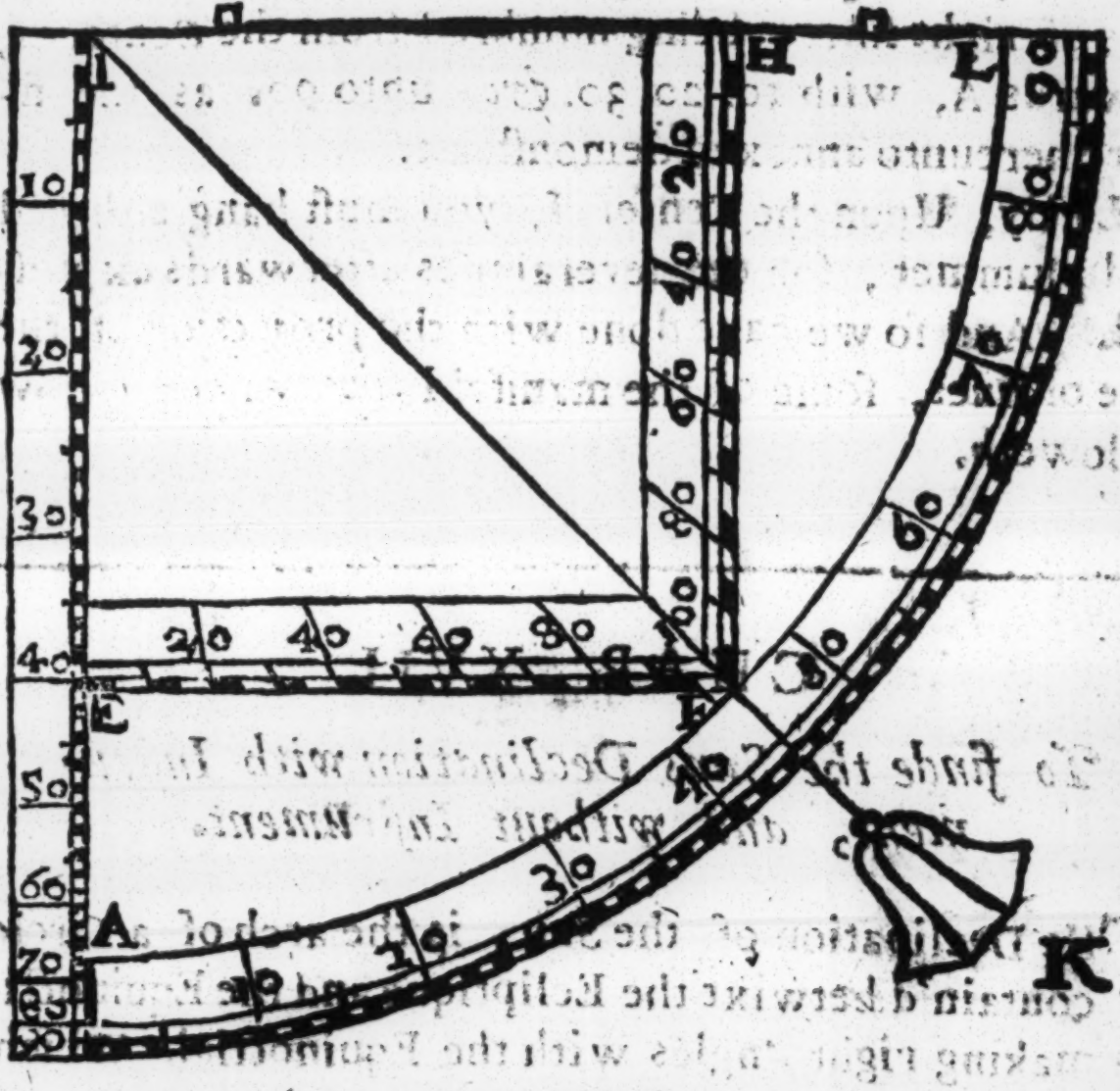
CHAP. XVI.

Containing a Succinct Deſcription of the Geometricall *Quadrant, and of the manifold uſes thereof.*

IN the twentieth ſix Chapter of my *Uranoſcopia*, you are taught how to make a Quadrant, with the Quadrat, and alſo how to devide and number the ſame: And therefore I ſhall not (now) repeat the ſame; but ſhall only ſhew the projection of a natural line of

fines

ſines upon the edge of the Quadrant, by help whereof, the Suns Azimuth, and the hour of the day, with other propoſitions in *Aſtronomy* or *Navigation*, may exactly, eaſily and ſpeedily be known.



And therefore ſuppoſe *I A F L* to be a Quadrant, whoſe limb *A F L* is devided into 90 equal parts, called degrees, and the ſides of the Quadrant, *viz.* E F and H F, devided into as many equal parts as quantity will permit, which here, we will ſuppoſe to be into 100. as the Figure demonſtrats.

Then let the Semidiameter A I, be devided into 90 unequal parts, called right ſines, by taking the neereſt extent,

extent, from each degree of your Quadrants limb A F L, unto the side I H L: and so placing those extents upon the side A I, each after other, from the Center I, towards A, so shall the Semidiameter or Radius I A, be devided unequally into 90 parts, called a line of right sines, being numbred from the Center I, towards A, with 10, 20, 30, &c. unto 90. as the figure hereunto annexed demonstrats.

Lastly, Upon the Center I, you must hang a threed and plummet, for the several uses afterwards expressed. And so we have done with the projection of the line of sines, some of the manifold uses whereof now followeth.

CHAP. XVII.

To finde the Suns Declination with Instrument, and without Instrument.

THe Declination of the Sun, is the arch of a Circle contain'd betwixt the Ecliptique and the Equinoctiall, making right Angles with the Equinoctial. Which in the figure of the tenth Chapter, may be represented unto you by the arch F Y, or F W: Or (upon the opposite end of the Equinoctial) by the arch W Θ, or W X. This declination of the Sun may be accounted either Northwards or Southwards, according to the scituation of the Sun: That is to say, as he is neerer unto the North or South Pole of the world.

The Sun hath North Declination, if the day be more then twelve hours long, and South Declination, when the

the day is lesse then twelve hours long. Or more plainly thus, from the time that the Sun enters ♈ *Aries*, untill he come to the beginning of ♎ *Libra*, (that is from the 9 or 10 of *March*, to the 12 or 13 of *September*) the ☉ Sun hath North declination: And from the time he enters ♎ *Libra*, till he come again to enter ♈ *Aries* (which is from the 12 or 13 of *September*, to the 9 or 10 of March) the ☉ Sun hath South declination. But that nothing might be wanting, and not much to trouble the Learner, I have here added a Table shewing the ☉ Suns declination, at Noon, every 5, 10, 15, 20, 25 and 30 dayes of the respective Moneths; of which more anone. But to our purpose, to find the Suns declination Instrumentally by the Quadrant.

First, lay the threed upon 23 deg. 30 min. (being the ☉ Suns greatest declination) counted upon the limb of the Quadrant. Then take the neareſt extent thereunto, from the sine of the ☉ Suns distance from the next Equinoctial point, and this distance being applyed to the line of sines from the Center I, shall give you the sine of the ☉ Suns declination required.

As for Example, Suppose the ☉ in the 24 degree of *Aries*, or *Libra*, his declination will be found 9 deg. 20 min. Or if the ☉ be supposed in the 18 degree of ♉ *Taurus*, or ♏ *Scorpio*, (both which points are 48 degrees distant from their neareſt Equinoctial points of ♈ and ♎) his declination will be found 17 deg. 15 min. as was required.

But if the Reader have no Instrumental Quadrant, and yet be desirous to know the Suns declination: Therefore enter the following Table with the 5, 10, 15,

15, 20, 25, or 30 day of your Month, finding the first dayes on the top, and the Moneths on the Margent, and in the common Angle you will finde by inspection the Suns declination: and by the rule of proportion for any other intermediate day. And although I have here fitted this following Table of the Suns declination, for every 5, 10, 15, 20, 25, or 30 dayes of the respective Moneths (correspondent to the true place of the Sun) at noon for the year, 1666. Yet generally without sensible error, it may serve (for the purpose here intended) for ever, which Table take as followeth.

A Table of the Suns Declination, for every 5 day at Noon, exactly calculated for the Year 1666. which (without sensible error) will serve for ever.

Names of the Months	5 day d.	m.	10 day d.	m.	15 day d.	m.	20 day d.	m.	25 day d.	m.	30 day d.	m.
January	21	04	20	03	18	51	17	30	16	03	14	29
February	12	28	10	42	08	51	06	58	05	03		
March	01	53	00	05	02	03	04	00	05	55	07	48
April	10	00	11	45	13	24	14	58	16	26	17	48
May	19	02	20	01	21	05	21	54	22	32	23	02
June	23	24	23	31	23	27	23	15	22	51	22	17
July	21	34	20	43	19	40	18	31	17	15	15	51
August	14	02	12	24	10	43	08	56	07	07	05	12
September	02	55	00	59	01	00	02	56	04	53	06	54
October	08	41	10	31	12	17	13	58	15	34	17	03
November	18	41	19	53	20	55	21	48	22	38	23	03
December.	23	25	23	31	23	28	23	12	22	45	22	05

The

The uſe of this Table, and the practical part thereof, is this: Suppoſe it were required to find the Suns declination, the 15 day of *April*, I look in the Table for the 15 day, and deſcending the ſaids Column, untill I come againſt the month of *April*, and in the common Angle, I finde 13 degrees, 24 minuts, which is the true declination of the Sun at noon the ſaids 15 day of *April* (1666.) as was required. In like manner, the 15 day of *May*, the Sun hath 21 degrees, 5 minuts of declination, the 15 day of *June*, 23 degrees, 27 minuts, and the 15 day of *July* 19 degrees, 40 minuts of declination, *&c.*

But if you would know the Suns declination for any other intermediate day, take the difference, and work by the Golden Rule, and you ſhall finde the proportionall part; to be added, if the Suns declination be increaſing, and to be ſubſtracted, if it bee diminiſhing: and ſo the ſum or difference will bee the true declination of the Sun (at noon) for the ſaids intermediate day as was required.

Example, I deſire to know the Suns true declination the 23 of *Auguſt*, I look into the Table, and I finde the Suns declination, for the 20 of *Auguſt*, 8 deg. 56 min., and for the 25 day, 7 deg. 7 min. The difference (of the Suns declination) in 5 dayes is 1 deg. 49 min. Then I ſay——If the Sun in 5 dayes decline 1 deg. 49 min. (or 109 min. being reduced) how much will hee decline in 3 dayes? *Anſ.* 60 min. and becauſe the Suns declination is deminiſhing, therefore I ſubſtract it from the Suns declination the 20 day, *viz.* 8 deg. 56 min. The remainder 7 deg. 56 min. is the Suns declination at noon the ſaids 23 day of *Auguſt*, (1666) as was required.

Here

Here note, that the Suns declination increaſſes, during the Suns motion through ♈, ♉, ♊, (and there oppoſite ſigns) ♎, ♏, and ♐ (which is from the 9 or 10 of *March*, till the 9 or 10 of *June*; and likewiſe from the 11 or 12 of *September*, till the 10 or 11 of *December*.) But deminiſhes all the time he moves through ♋, ♌, ♍, (or their oppoſits) ♑, ♒, and ♓, (which is from the 10 or 11 of *June*, to the 11 or 12 of *September*, and from the 10 or 11 of *December*, to the 9 or 10 of *March*,) as the Table it ſelf ſufficiently demonſtrats.

CHAP. XVIII.

To finde the Suns Amplitude with, and without Inſtrument.

THe Amplitude of the ☉ Sun, is nothing elſe but the diſtance of his riſing or ſetting from the true point of East or West, and will be found by taking the ſine of the ☉ Suns declination betwixt your Compaſſes, and with this diſtance ſet one foot in the Co-ſine of the Latitude, and with the other lay the threed to the neareſt diſtance, ſo ſhall it ſhew upon the Quadrant limb, the ☉ Suns *Amplitude* required.

Example, Suppoſe the ☉ Suns declination 9 deg. 20 min. and the Latitude of the place 56 degrees (whoſe Co-ſine or Complement to 90 degrees, is 34 degrees) hence the ☉ Suns Amplitude will be found about 16 deg. 53 min.

Or, Suppoſe the ☉ Suns declination 11 deg. 45 min. and

and the Latitude of the place 50 deg. 30 min. his Amplitude will be found 18 deg. 40 min. as was required.

Without Instrument to find the ⊙ Suns Amplitude, enter the following Table with the 5, 10, 15, 20, 25, or 30 day of your Month on the top, and your Month in the *Margent*, and in the common Angle you will find the ⊙ Suns Amplitude required, which will be equal to his Amplitude for the saids dayes of the opposite Moneths, if the quantity of the ⊙ Suns declination be alike.

A Table of the Suns Amplitude, every 5 day, of the respective Months within written: Exactly Calculated for the Latitude of *Edinburgh*, which is 56 deg. 4 min.

Names of the Months	5 day d.	m.	10 day d.	m.	15 day d.	m.	20 day d.	m.	25 day d.	m.	30 day d.	m.
January	40	05	37	53	35	22	32	36	29	41	26	37
February	22	45	19	25	16	00	12	33	09	04		
March	03	23	*Sept.*		01	47	05	09	08	46	12	25
October	15	41	19	05	22	24	25	37	28	44	31	41
November	35	01	37	32	39	46	41	42	43	35	44	32
December.	45	24	45	40	45	31	44	54	43	51	42	22

Example, Suppose it were required to finde the ⊙ Suns Amplitude the tenth day of *January*. I look in the Table and finds it 37 deg. 53 min. and in like manner the tenth of *February*, 19 deg. 25 min. The tenth of *March*, it is 00 deg. 00 min. and there the Month of *September* begins; upon the 15 day thereof, the ⊙ Suns Ampli-

Amplitude is 1 deg. 47 min. the 20 day thereof, it is 5 deg. 9 min. *&c.*

I have omitted the Calculation of the ⊙ Suns Amplitude for the Months of *March*, *April*, *May*, *June*, *July*, and *Auguſt*; They that have uſe for it (and ſkill to Calculate) will ſee a rule to finde it, in the fourth propoſition of the 21 Chapter of my *Uranoſcopia*, to which *I* refer you.

Here note, that you are to finde the ⊙ Suns Amplitude for the intermediat dayes, as you do the ⊙ Suns declination for the ſaids dayes.

CHAP. XIX.

To finde the Suns heighth in the Verticall Circle, with, and without Inſtrument.

THe ⊙ Sun is ſaid to be in the Vertical Circle in any Horizon, when he is due Eaſt or Weſt, which is only in Summer time, *viz.* when the day is more then 12 hours long, at which time his true Altitude or heighth, when he is Eaſt or Weſt, may be found thus,

Take the ſine of the ⊙ Suns declination betwixt your Compaſſes, and with this diſtance, ſetting one foot in the ſine of the Latitude, with the other lay the threed to the neareſt diſtance, ſo ſhall the threed upon the limb, ſhew the heighth of the ⊙ Sun in the Verticall Circle.

Example, Suppoſe the ⊙ Suns declination (Northwards) 9 deg. 20 min. and the Latitude of the place 56 degrees, his heighth in the Verticall Circle will be

11 deg.

11 deg. and about 18 min. Or the declination 11 deg. 45 min. and the Latitude 50 deg. 30 min. his heighth when he is due East or West will be 15 deg. 18 min. as was required.

Without Instrument to find the Suns Altitude in the Vertical Circle, Enter the following Table, with the 5, 10, 15, 20, 25 or 30 day of your Month, and in the common Angle you will find the Suns Altitude in the Vertical Circle. As for Example, Suppose it were required to find the saids Altitude of the Sun in the Vertical Circle, the 15 day of *April*, I look into the Table and finds it 16 deg. 13 min. The 20 of *May* it is 26 deg. 43 min. The 25 of *June* 27 deg. 54 min. &c. For the intermediate dayes, you are to find it, as I shewed you in the Suns declination.

A Table of the Suns Altitude in the Vertical Circle, for every 5 day of the Moneths within written, Calculated for the Latitude of 56 deg. 4 min.

Names of the Months	5 day		10 day		15 day		20 day		25 day		30 day	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
March	00	00	00	00	02	28	04	50	07	08	09	25
April	12	05	14	12	16	13	18	08	19	56	21	37
May	23	09	24	22	25	42	26	43	27	30	28	08
June	28	38	28	46	28	40	28	25	27	54	27	12
July	26	18	25	14	23	56	22	30	20	56	19	13
August	17	00	15	00	12	39	10	47	08	35	06	16
September	03	31	01	11	00	00	00	00	00	00	00	00

CHAP.

CHAP. XX.

To finde the Suns Altitude, or Depreſſion, at the hour of ſix, with, and without Inſtrument.

First, Lay the threed upon the ☉ Suns Declination counted on the limb of the Quadrant. Then from the ſine of the Latitude, with your Compaſſes take the neereſt extent unto the threed. And that extent or diſtance, applyed to the line of ſines from the Center A, ſhall be the ſine of the ☉ Altitude in Summer Or Depreſſion in Winter, at the hour of ſix.

Example, Suppoſe the ☉ Suns Declination to be 9 deg. 20 min. and the Latitude of the place, 56 degrees, you will find the ☉ Suns Altitude, above the Horizon, in the Summer time, or Depreſſion under the Horizon in the Winter time, to be 7 degrees, 44 minuts.——Or ſuppoſe the Latitude of the place to be 50 deg. 30 min. and the ☉ Declination 11 deg. 45 min. Northwards, his Altitude above the Horizon, at the hour of ſix, will be 9 deg. 2 min. But had the ☉ Suns Declination been Southwards, it would have been the ſame 9 deg. 2 min. of Depreſſion, at the hour of ſix, as was required.

The Altitude or Depreſſion of the Sun at the hour of ſix, may be found without Inſtrument, by entering the following Table (as is before ſhewed) with your Month and Day, &c. As for Example, The 25 of *January*, you will find the Suns Depreſſion (under the

the Horizon) at the hour of six, 13 deg. 16 min. The 15 of *February*, 7 deg. 20 min. of Depression. The 20 of *March*, the Altitude of the Sun at the hour of six, is 3 deg. 19 min. And the 30 of *May*, 18 deg. 57 min. &c. as the Table succinctly demonstrats.

A Table of the Suns Altitude, and Depression, at the hour of six, every 6 day: Exactly Calculated for the Latitude of 56 degrees, 4 minuts.

Names of the Months	5 day		10 day		15 day		20 day		25 day		30 day	
	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.	d.	m.
January	17	21	16	32	15	33	14	27	13	16	12	00
February	10	19	08	52	07	20	05	46	04	11		
March	01	34	00A	04	01	42	03	19	04	53	06	28
April	08	17	09	43	11	05	12	22	13	35	14	42
May	15	43	16	30	17	22	18	02	18	32	18	57
June	19	14	19	20	19	17	19	07	18	47	18	20
July	17	45	17	04	16	13	15	17	14	14	13	06
August	11	36	10	16	08	53	07	25	05	54	04	18
September	02	25	00	49	00D	50	02	26	04	03	05	43
October	07	11	8	43	10	10	11.	33	12	52	14	05
November	15	25	16	24	17	14	17	57	18	37	18	57
December.	19	15	19	20	19	18	19	05	18	43	18	11

CHAP. XXI.

To find the Suns Azimuth by the Quadrant.

YOu must first know the Latitude of your place, the ⊙ Suns Altitude and Declination. Then if the Sun's

NATIONAL LIBRARY OF SCOTLAND

Suns Declination be Northwards, (which the 17 Chapter will ſhew you.) By the 19 Chapter, finde his heigth in the Vertical Circle, for the day propoſed. From the fine of which, take the diſtance unto the fine of the Suns Altitude obſerved. And with this diſtance, ſetting one foot of your Compaſſes in the Co-fine of your Latitude, with the other lay the threed to the neereſt diſtance, which threed, let it lye ſtill in that poſition: And ſetting one foot of your Compaſſes in the fine of the Latitude, and with the other take the neereſt extent unto the threed. And with this diſtance, ſet one foot in the Co-fine of the ⊙ Suns Altitude; with the other foot, lay the threed again to the neereſt diſtance: ſo ſhall it ſhew upon the limb the ⊙ Suns Azimuth from the Eaſt or Weſt, towards the North or South.

Example firſt, Suppoſe the Latitude of the place, to be 56 degrees, and the ⊙ Suns Altitude obſerved (by a Quadrant) in the forenoon, 36 deg. 45 min. and the ⊙ Suns Declination Northwards 14 deg. 45 min. By which Declination, I find the Suns heighth in the Vertical Circle to be 17 deg. 53 min. And conſequently, his Azimuth from the Eaſt towards the South, 32 deg. 34 min. as was required.

But if the ⊙ Altitude obſerved, *viz.* 36 degrees, 45 minuts, had been in the afternoon, having the ſame Declination Northwards, *viz.* 14 degrees, 45 minuts. Then the ⊙ Suns heighth in the Vertical Circle, will be found (as before) 17 degrees, 53 minuts. But his Azimuth will (now) be from the Weſt towards the South, the ſame 32 degrees, 34 minuts, as was required.

Example

Example ſecond, In the Latitude of 56 deg. the 19 day of *April*, 1665. in the afternoon: *I* obſerved with my Quadrant the ⊙ Suns Altitude, and found it 43 deg. 45 min. The ⊙ Sun then having 14 deg. 45 min. of North declination, by which *I* found (according to the 19 Chapter) the ⊙ Suns Altitude in the Verticall Circle 17 deg. 53 min. and conſequently his Azimuth from the Weſt, towards the South, 54 deg. 15 min. as was required.

Here note, that when the declination of the ⊙ Sun is North-ward, if the Altitude of the ⊙ Sun obſerved, and his heighth in the Verticall Circle be equal, then is the ⊙ Sun directly Eaſt or Weſt. But if the ⊙ Suns Altitude obſerved be greater: then is his Azimuth towards the South. And if it be leſſer, it is towards the North.

But, if the declination of the ⊙ Sun be Southward, then by the 18 Chapter, finde the ⊙ Suns Amplitude for the day propoſed. This done, take the ſine of the ⊙ Suns Altitude obſerved, and with this diſtance ſetting one foot in the Co-ſine of the Latitude, with the other lay the threed to the neareſt diſtance, and letting the threed ly ſtill in this poſition, take the neareſt extent thereunto from the ſine of the Latitude. And this diſtance add to the ſine of the ⊙ Suns Amplitude, (by ſetting one foot in the ſine of the Amplitude, and extending the other upon the line of ſines.) Theſe two being thus joyned, take them betwix your Compaſſes, and ſetting one foot in the Co-ſine of the ⊙ Suns Altitude, with the other lay the threed to the neareſt diſtance, ſo ſhall it ſhew upon the limb, the ⊙ Suns Azimuth from the Eaſt or Weſt, towards the South.

Example first, Suppose the Latitude of the place to be 56 degrees, and the ⊙ Suns Altitude observed (by a Quadrant) in the forenoon 17 deg. 30 min. and his declination 11 deg. 30 min. Southwards. By which Declination, I find the Suns Amplitude (according to the 18 Chapter) 20 deg. 53 min. And consequently the Suns Azimuth from the East towards the South, 57 deg. 8 min. as was required.

Example second, In the saids Latitude of 56 degrees, the Suns Altitude observed in the afternoon, 9 deg. 15 min. and the Suns declination 20 deg. 12 min. Southwards, his Amplitude will bee found 38 deg. 26 min. and his Azimuth 60 deg. 35 min. from the West towards the South, as was required.

I have been large in this Chapter, because of the excellent uses that is to be made thereof, both for Sea and Land. For by knowing the Azimuth, or point of the Compasse, that the Sun bears from us, its easie to finde a true Meridian line, and thereby the Coasting of a Countrey, the Site of a Building, and Variation of the Compasse, &c. Of which, *I* shall briefly touch, in their proper place.

CHAP. XXII.

To find the Hour of the Day by the Quadrant.

IF the declination of the ⊙ Sun be Northwards, find the heighth of the ⊙ Sun, at the hour of six (according to the 20 Chapter) betwixt which sine, and the sine of the ⊙ Suns Altitude observed. Take the distance

ſtance upon the line of ſines, with which diſtance, ſetting one foot in the Co-ſine of the Latitude, with the other lay the threed to the neareſt diſtance, and ſo let it ly ſtill in that poſition: Then ſetting one foot of your Compaſſes in the ſine of 90 degrees, with the other take the neareſt extent unto the threed, and with this diſtance, ſetting one foot in the Co-ſine of the ☉ Suns declination, with the other lay the threed to the neareſt diſtance, ſo ſhall it ſhew upon the limb, the quantity of time, from the hour of ſix.

Example firſt, Suppoſe the Latitude of the place to be 56 degrees. And the ☉ Suns Altitude obſerved (in the forenoon,) 26 deg. 15 min. and his declination 13 deg. 8 min. By which *I* finde his Altitude at the hour of ſix, to be 10 deg. 45 min. and conſequently the threed upon the limb falls on 28 deg. 00 min. which converted into time (by allowing 15 degrees to an hour, &c.) gives one hour 52 min. paſt ſix, that is 8 min. before eight a clock in the morning.

Example ſecond, The Latitude being (as before) 56 degrees, and the ☉ Suns altitude obſerved 33 deg. 15 min. and his declination 20 deg. 12 min. his Altitude at the hour of ſix, is 16 deg. 30 min. and conſequently the threed upon the limb falls on 30 degrees, that is two hours from ſix, which is four a clock in the afternoon.

Here note, that when the declination of the Sun is Northwards, if the Altitude of the Sun obſerved, and his Altitude at the hour of ſix bee equal, then it is juſt ſix a clock: But if the Altitude obſerved bee greater: then is the time found, to the Southward of the hour of ſix. And if it be leſſer, it is to the Northwards of the hour of ſix.

But if the Suns declination be Southwards, take the fine of the Suns depreſſion at the hour of ſix, (according to the ſaids 20 Chapter) and adde it to the fine of the Suns Altitude obſerved, (by ſetting one foot in the fine of the Suns Altitude, and extending the other upon the line of fines.) Theſe two being thus joyned together in one, take them betwixt your Compaſſes, and ſetting one foot in the Co-fine of the Latitude (as before) with the other lay the threed to the neareſt diſtance, which let ly ſtill in this poſition. And from the fine of 90 degrees, take the neereſt extent thereunto. And with this diſtance ſetting one foot of your Compaſſes in the Co-fine of the Suns Declination, with the other lay the threed to the neereſt diſtance, ſo ſhall it ſhew upon the limb, the quantity of time from the hour of ſix.

Example firſt, Suppoſe the Latitude of the place to be 56 degrees, and the Suns Altitude obſerved in the forenoon, 18 degrees, 00 minuts. And his declination 11 degrees, 30 minuts. Hence his depreſſion at the hour of ſix, is, 9 degrees, 30 minuts: And conſequently the threed will fall upon 60 degrees, 00 min. on the limb, that is, four hours from ſix, and therefore the time of the day is ten a clock in the forenoon.

Example ſecond, The Latitude 56 degrees, and the Suns Altitude obſerved (in the afternoon) 7 degrees, 8 minuts, and his declination 20 degrees, 12 minuts. Hence his depreſſion at the hour of ſix is 16 deg. 38 min. And conſequently, the threed will fall upon 52 deg. 30 min. whoſe complement, 37 deg. 30 min. converted into time, makes two hours, 30 min. for the time of the day, as w as required.

But ſometimes, (at Sea eſpecially) you will not at firſt know, whether it be forenoon or afternoon; but this may be eaſily known by making a ſecond obſervation with your Quadrant; and then, if you find the Sun to riſe higher, it is the forenoon; but if it become lower, it is the afternoon.

CHAP. XXIII.

To finde the Declination of any Wall or Plane by the Quadrant.

THe declination of any Wall or Plane, is nothing els but the diſtance (or number of degrees and minuts) between the Horizontal Line of the ſaids Wall or Plane, and the line of Eaſt and Weſt. And therefore to find the ſame: Firſt, Draw an Horizontal (or Levell) line, upon the Wall or Plane, apply the ſide of your Quadrant thereunto, ſo as the limb may be towards the Sun, and the plane of the Quadrant may lye parallel to the Horizon. Then having a looſe Threed and Plummet, hanging it down at liberty in your right hand, cloſs by the edge or limb of the Quadrant: move your hand hither and thither, until the ſhaddow of the threed paſſe directly through the Center of the Quadrant. Which done, obſerve how many degrees and minuts the ſhaddow cuts, from that ſide of the Quadrant which is perpendicular to the Horizontal line. For that Angle is called the Horizontall diſtance. At the ſame moment of time (Or as neer as may be) obſerve the Suns Altitude, by which you

you are to find the Suns Azimuth from the *South*, according to the 13, or 21 Chapters.

After this, consider whither the shaddow of the threed did fall betwixt the South, and the Perpendicular side of the Quadrant. Or whether the same shaddow did fall so, as to leave both the South, and the said Perpendicular side (both of them) upon one coast of the shaddow.———In the first case, you must adde the Horizontal distance to the Suns Azimuth. In the latter ease, you must substract the lesser out of the greater. The result (whither it be sum or difference) gives the declination of the plane from the South towards the East or West.

Here note, in the first case, that if the sum of the Horizontal distance and Azimuth, do exceed 180 degrees, then the planes declination from the *South*; is (contrary to that Coast whereon the Sun stood, and will be) found by substracting the forementioned sum out of 360 degrees. This happens more seldome, that is, only upon some North Planes, and on them too: Only then when the *Suns* Azimuth is more then 90 degrees from the *South*, and the Horizontal distance more then is the *Suns* Azimuth from the North.

Moreover, in the second case, you must note also, that if the Horizontal distance, bee greater then the ⊙ Suns Azimuth: then doth the plane decline to that Coast (East or West) which is contrary to the Coast on which the ⊙ *Sun* stood from the South, and this falls out very frequently.

Example fifst, *May* 16, 1665. in the forenoon, *I* made tryal of the declination of a Wall, and holding the edge of my Quadrant (levell) clos to the Wall, *I* observed

obſerved that the ſhadow of the threed did fall betwixt the South, and the *Perpendicular* ſide of the Quadrant on 15 degrees (from that ſide of the Quadrant, which was *Perpendicular* to the Horizontal line) and ſo much was the Horizontal diſtance. ——Immediatly after, *I* obſerved the ⊙ Suns Altitude, and found it 50 deg. 15 min. having North declination 21 deg. 16 min. Hence (according to the 13 or 21 Chapters) *I* found the ⊙ Suns Azimuth from the South, towards the Eaſt, 38 deg. 30 min.

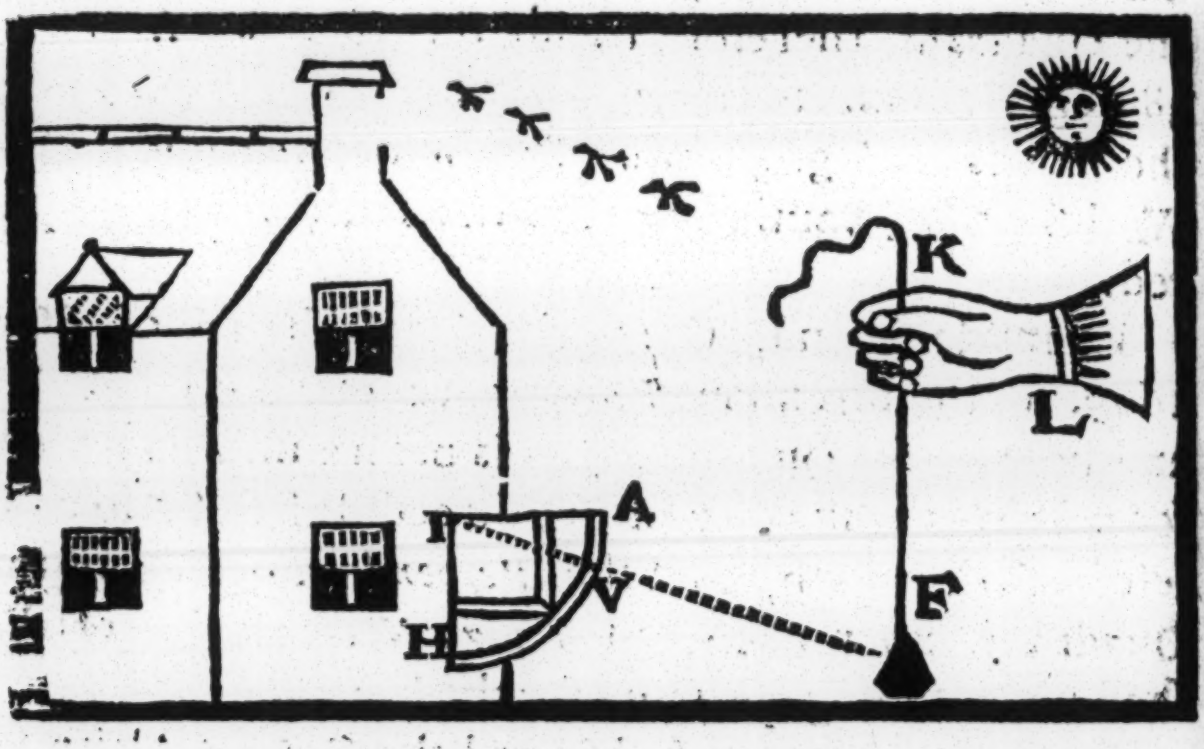
Now conſidering that the ſhadow of the threed did fall betwixt the South, and the *Perpendicular* ſide of the Quadrant, therefore *I* adde the ⊙ Suns Azimuth 38 deg. 30 min. unto the Horizontal diſtance 15 deg. the ſum is 53 deg. 30 min. for the declination of the Wall from the South, towards the Eaſt, as was required.

Example ſecond, Upon the foreſaids 16 of *May*, 1665. in the forenoon, *I* made tryal of another Wall; and holding my Quadrant (as is before ſhewed) *I* obſerved that the ſhadow of the threed did fall (ſo as it left both the South, and the *Perpendicular* ſide of the Quadrant, upon one Coaſt (*viz.* Weſtward) of the ſhadow) 49 deg. 30 min. for the Horizontal diſtance; ——Preſently after, *I* obſerved the ⊙ Suns Altitude, and found it 53 deg. 30 min. his declination being (as before) 21 deg. 16 min. Hence his Azimuth from the South, towards the Eaſt, was 20 degrees.

Now conſidering that the ſhaddow of the threed did fall ſo, as it left both the South, and the *Perpendicular* ſide of the Quadrant, upon one Coaſt (*viz.* Weſtward) of the ſhadow; Therefore, *I* ſubſtract the ⊙ Suns Azimuth,

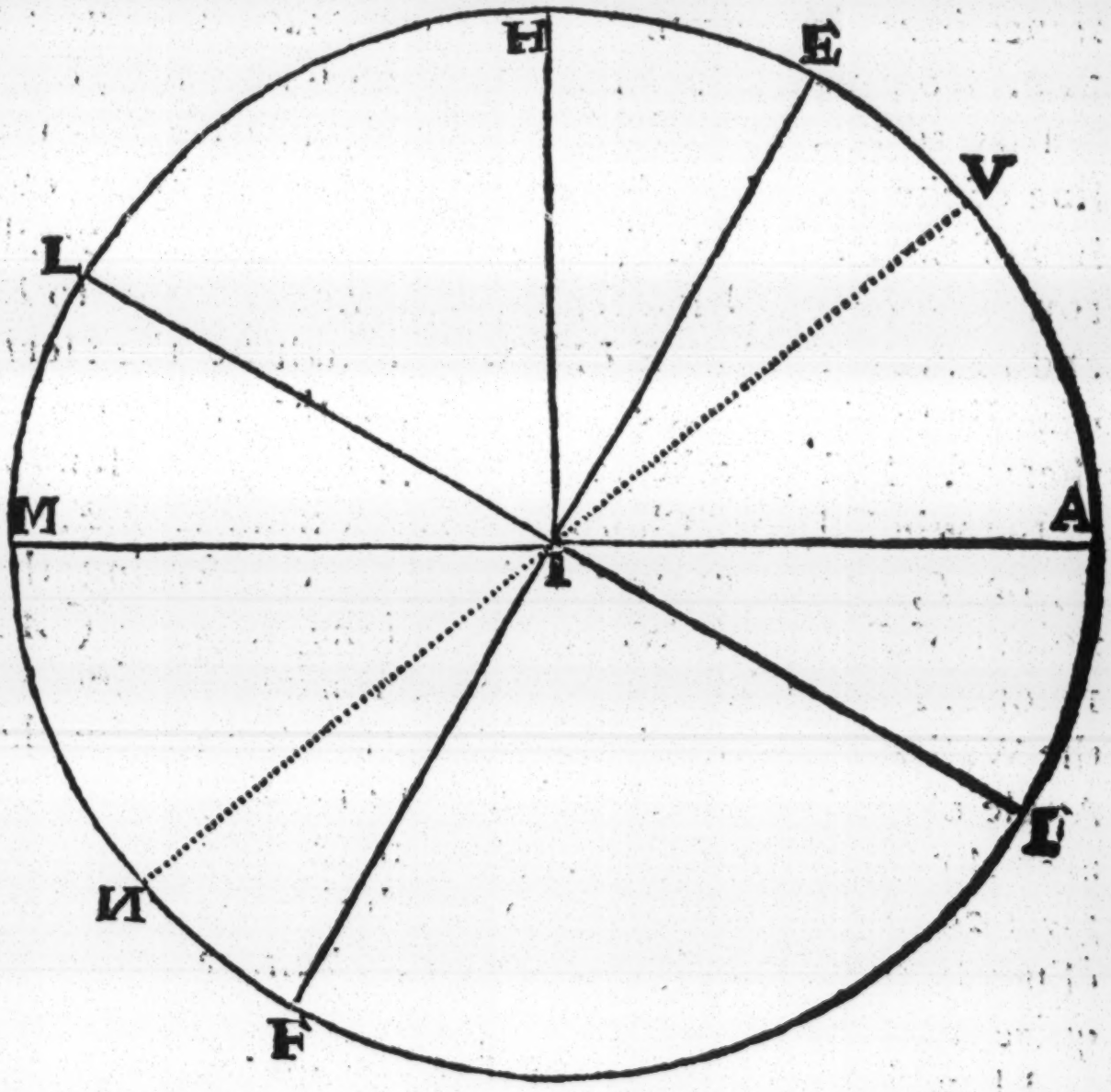
much 20 deg. 00 min. being the leſſer number, from the Horizontal diſtance 49 deg. 30 min. being the greater, and the Reſidue 29 deg. 30 min. is the true declination of the Wall, from the South towards the Weſt, as was required.

Moreover, becauſe the Horizontal diſtance is greater then the Suns Azimuth from the South, this ſhews that the plane or Wall declines from the South towards that Coaſt (*viz.* Weſtwards) which is contrary to that Coaſt (*viz.* Eaſtwards) where the Sun was from the South at that time of the obſervation.



For the better illuſtration of the premiſſes, *I* ſhall here demonſtrate, and that Geometrically, how the declination of a Wall may be found, as in the laſt example: wherefore holding the edge of my Quadrant A I, to the (gavell or) Wall of this houſe, the other ſide of the Quadrant, *viz.* I H, muſt needs be *Perpendicular* to the Horizontal or level line drawn on the Wall.

Wall. The Sun ſhining, I hang forth a Line and Plumet as F K, moving it to & fro, until the ſhadow thereof fall upon the Center I, at which time ſuppoſe the ſaids ſhaddow falls on 49 deg. 30 min. (being counted from the *Perpendicular* ſide I H,) from *H* to V, his Altitude being 53 deg. 30 min. and conſequently his Azimuth



from the South, towards the Eaſt, was 20 degrees; this being known, with your Compaſſes opened to the Radius of the line of Chords, deſcribe the Circle *AVEHLMNF*, repreſenting the Horizontal Circle, through

through the Center *I*, draw the line *A I M*, which ſhall repreſent the Horizontal line *A I*, made (by the edge of your Quadrant) upon the Wall. Then devide *A H M*, into two equal parts, the midſt is *H*, by which point *H*, and the Center *I*, draw the line *I H*, repreſenting the *Perpendicular* ſide of the Quadrant *I H*, in the former Figure. Now ſeeing the Horizontal diſtance is 49 deg. 30 min. therefore take 49 deg. 30 min. from your line of Chords, and ſet from *H*, Eaſtwards, to *V*, and ſo draw the line *V I*, repreſenting the line of the ſhaddow. Then take 20 degrees from your line of Chords (being the Suns *Azimuth* from the *South* towards the Eaſt) and ſet from V *South*wards to *E*, and ſo draw the line *E I F*, which ſhall be the Meridian line: *E* being the *South*, and *F* the North points thereof. Laſtly, take 90 degrees, (being the length of the whole line of Chords) and ſet from *E* or *F*, to r, or *L*, and ſo draw the line *I L*, repreſenting the points of *Eaſt* and Weſt, ſo ſhall the Triangle (*A I* r, or *L I M*) made between the Horizontal line of the Wall *A I*, and the line of *Eaſt* or Weſt *I* r, be the Angle of the Walls declination here required. Which arch *A* r (or *L M*) being applyed to the line of Chords gives 29 deg, 30 min. and ſo much the ſaids Wall declines from the *South*, towards the Weſt, as was required.

I have been the larger in theſe examples, becauſe *I* would have the Reader to underſtand and practice the ſame, for the finding of the declination of a Wall, this way *I* have preſcribed is infallible, whereas the Needle and Compaſſe (though never ſo large) is (in every

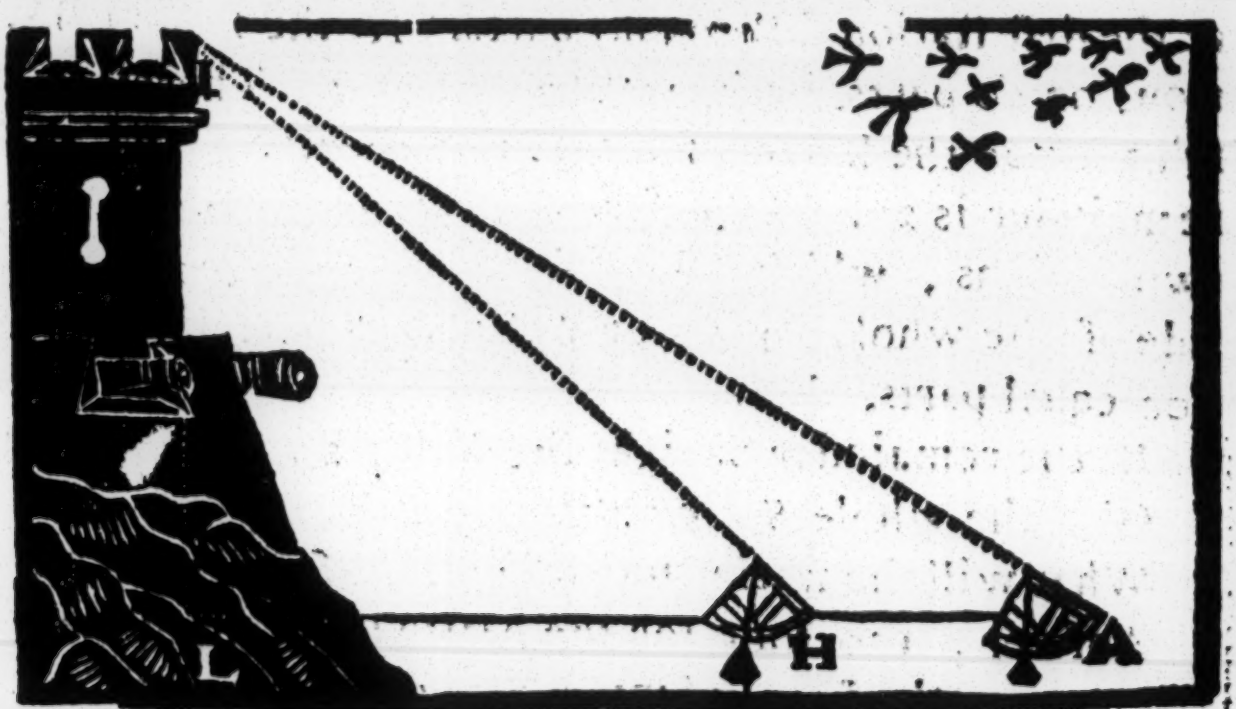
Climate

Climate) ſubject to Variation, and conſequently cannot exhibit the true declination of any Wall.

CHAP. XXIV.

To finde the exact heighth of a Hill, Tower, Caſtle, or Steeple, that is Inacceſſible: by the Quadrant.

A Caſtle, Hill, Tower, or Steeple, may happen to be ſo ſcituate, as it may be either difficult, (dangerous,) or altogether impoſſible to advance to the baſe thereof, by reaſon of Rocks, Hills, deep Rivers, Lochs, Ditches, or Moſſes, &c. Or dangerous for a mans life, be the enemies ſhot from the Caſtle or Tower. For which impediments we uſually call ſuch places Inacceſſible.



Now to finde the Altitude of any Houſe or Tower, that is acceſſible, *I* have already ſhewn you in the 27 Chapter

Chapter of my *Uranoſcopia*, and in this Chapter I ſhall briefly demonſtrate, how the exact heighth of places inacceſſible may be found.

Suppoſe it were required to finde the Altitude of this Tower.

You muſt make choice of two convenient ſtations, at which places hold up your Quadrant towards the Tower, looking through both the ſights thereof, untill you eſpy the very ſummity or top of the Tower. Then mark [the fall of the Plummet] where the threed and Plummet cuts the ſquare, or ſcale (of equal parts) and if the threed at both ſtations fall on that ſide of the ſquare next the ſights (called points of right ſhaddow.) Then ſubſtract the leſſer from the greater: And ſay, As the remainder, (of right ſhaddow) is to the whole ſcale, ſo is the diſtance between your ſtations, to the true heighth above the levell of your eye.

As for Example, Suppoſe the threed and Plummet at the firſt ſtation falls on 80 parts. At the ſecond ſtation, on 60 parts, both on *Umbra Recta*. Therefore I ſubſtract 60 the leſſer, from 80 the greater, and the remainder is 20. I meaſure the diſtance between my two ſtations, which I ſuppoſe to be 24 foot, and the ſide of the whole *Square* or *Scale* being devided into 100 equal parts, I ſay,

If the remainder of right ſhaddow 20
Give the whole *Scale* or Square 100.
What will the ſtationary diſtance 24 foot give?
Anſwer, 120 foot for the Altitude of the Tower above the Level of my eye, as was required.

The

The ſecond Rule.

But ſuppoſe at my firſt ſtation the Threed and Plummet ſhould fall on *Umbra Verſa*, and at the ſecond ſtation upon *Umbra Recta*: What ſhall I then do? *Anſw.* Reduce the parts of *Umbra Verſa*, into parts of *Umbra Recta*: thus, Multiply the ſide of your *S*quare or *S*cale by it ſelf, the product devided by the parts of *Umbra Verſa*, which the Threed and Plummet did fall on: The Quotient will be the parts of *Umbra Recta* (equal to the former parts of *Umbra verſa*) from which Quotient, ſubſtract the parts of *Umbra Recta*, which your Threed and Plummet did fall on, at your ſecond ſtation. Note the remainder, and meaſure the diſtance between your two ſtations. And then ſay as before, —— If the remainder, give the whole *S*quare; what will the ſtationary diſtance give? *Anſw.* The true Altitude required.

Example, *S*uppoſe the Threed and Plummet (at the firſt ſtation) fall on 25 parts of contrary ſhaddow, and at the ſecond ſtation, upon 80 of right ſhaddow. And ſuppoſe the diſtance between the two ſtations to be 400 foot (that is 133 yards 1—3) —— Now I multiply the ſide of my *S*quare (which is devided into) 100 (equal parts) by it ſelf (*viz.* 100) the product is 10000. which I devide by 25, (the parts of contrary ſhaddow, which the Threed and Plummet did fall on, at the firſt ſtation.) The Quotient is 400 (parts of right ſhaddow, equal to 25 of contrary ſhaddow) from which I ſubſtract 80. (The parts of right ſhaddow at the ſecond ſtation) reſts 320. This known, to find the Altitude of the Tower, I ſay as before.

If

If the remainder of right ſhaddow 320.
Give the whole *S*quare 100.
What ſhall the ſtationary diſtance 400 foot give?
Anſw. 125 foot, for the exact Altitude required.

The third Rule.

Finally, if at both your ſtations, the threed and Plummet falls upon contrary ſhaddow, then at your firſt ſtation (furtheſt off) hold up your Quadrant towards the Tower or Hill whoſe Altitude you require and obſerve diligently the parts of contrary ſhaddow, which the threed and Plummet falls on. Then ſuppoſe the heighth of the Tower, Caſtle or Hill to bee 20, 40, 80, 100, or a 1000 foot high, (for you may ſuppoſe any number whatſoever you pleaſe to bee the heighth thereof.) Then ſay, ——As the parts cut, Is to the whole Square; So is the ſuppoſed heighth (make it what you pleaſe as *I* ſaid before,) To the Quotient at the firſt ſtation.

Then advance to your ſecond ſtation (nearer hand to your object) ſome certain number of ſcores, paces, or foots, according as ſafety or convenience will permit (which your diſcretion will inform you) which done, at the ſaids ſecond ſtation, you are to obſerve there alſo by your Quadrant, (as before is ſhewed) the parts cut. Which known, then ſay again —— As the parts cut, is to the whole Square; ſo is the (former) ſuppoſed heighth, To the Quotient at the ſecond ſtation.

Laſtly, Theſe obſervations thus made, ſubſtract the leſſer Quotient from the greater; and the remainder will be the difference of the (two) Quotients. Likewiſe,

wiſe, Meaſure how many yards or foots, it is between your two ſtations: both which being known, then to finde the true Altitude of the Hill, or Caſtle, ſay,

As the difference of the Quotients, is to the diſtance between your ſtations; So is the former (ſuppoſed) heighth to the true heighth, above the level of your eye.

Example, Suppoſe *I* to be a Tower, built on a Hill, or Rock, whoſe Altitude, I deſire to know, above the Levell of my eye, ſtanding at my two ſtations H and A. Wherefore I make *A* my firſt ſtation (furtheſt off) where holding up my Quadrant towards *I*, I finde the threed and Plummet to fall on 10 parts of contrary ſhaddow, and *I* ſuppoſe the Altitude of the Tower and Rock *I L*, (above the Level of my eye) to bee 50 (or *I* might have ſaid a 100, or a 1000) foot high. ——Then, as the parts cut 10, is to the whole Square 100; So is my ſuppoſed heighth 50, to my firſt Quotient 500.

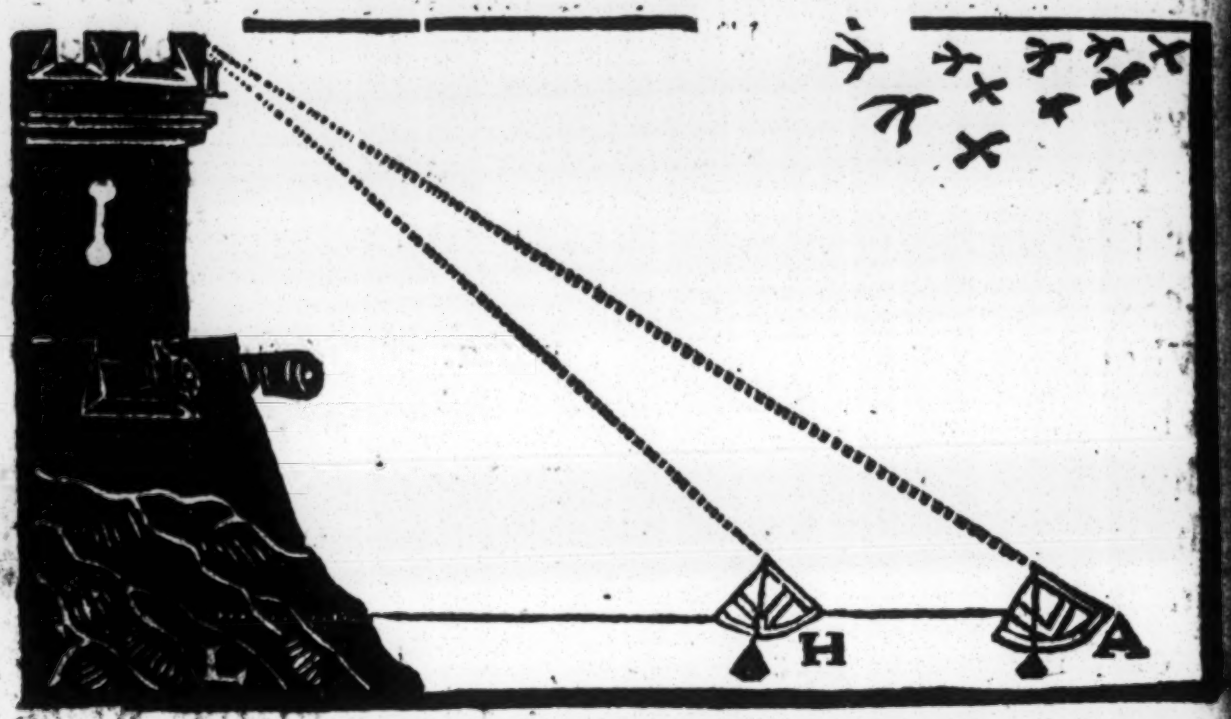
This done, *I* advance to my ſecond ſtation at H, where I find the threed and Plummet to fall on 25 parts of contrary ſhaddow; which known, *I* ſay again——As the parts cut 25, is to the whole Square 100; So is my former ſuppoſed heighth 50, to my ſecond Quotient 200, which ſubſtracted from the firſt Quotient 500, reſts 300 for the difference of the ſaids Quotients.

This done, *I* meaſure the diſtance between my two ſtations *A* and *H*, and (ſuppoſe) I finde it a 150 yards, that is 450 foot.

Finally, to finde the true Altitude I L, *I* ſay, —— As the difference of the Quotients 300, is to the ſtatio-

nary

nary diſtance *A H*, 450 foot; So is my (former) ſuppoſed heighth 50 foot, to the true Altitude of the Rock and Tower *I L*, 75 foot, above the Level of my eye, at A and H, as was required.



I have been the larger in theſe examples, partly becauſe I intend it as an Introduction to another greater work of Geometry, which I reſolve (God willing) to emit: and partly alſo, becauſe I would have the ignorant (for whoſe ſakes this is principally intended) with the better facility to underſtand the ſame; for when I was a young Student, theſe things were exceeding difficult to me, as having neither Author nor Teacher, for my addreſſe. But through the goodneſſe of God, and the irreſiſtable promptitude and innate inclination of my Genius; Maugre all difficulties (enough to have cruſht my intentions, when they firſt budded, yet) I obtained that which I ſo much deſired.

CHAP.

CHAP. XXV.

To find the exact distance to the Perpendicular *base and Top of any high Hill, Castle, or Tower, by the* Geometrical *Quadrant.*

TO doe this, you must first know (by help of two stations) the true Altitude of the saids Hill, Castle or Tower, according to the Preceeding Chapter: together with your two Quotients, and their Quotient Difference, made at your two Stations; and haveing measured the Distance between the saids Stations. Then to finde the Distance from your first Station, to the *Perpendicular* base of the Hill, Castle, or Tower. Say ——As the difference of the Quotients, is to the distance between your stations: So is the Quotient (number) made at the first station, to the true distance between the *Perpendicular* base of the Hill, or Tower, and the first station. From which, if you substract the distance between your two stations: The residue will be the exact distance of the *Perpendicular* base of the saids Hill, Tower, &c. from the second station.

But to finde the *Hypothenusall* distance, that is, the distance ascending between your eye, (at either of your stations,) and the *Perpendicular* Top of the Hill, or Tower, &c. add the Square of the length of the base, unto the Square of the Hill or Towers height; The Square root of the aggregate will be the *Hypothenusall* distance required.

Example, In the preceeding Chapter, from the le-

vell of my two ſtations H,& A, I found the Altitude L I, to be 75 foot, and the firſt Quotient [anſwering to my firſt ſtation at A] is 500, and the ſecond Quotient 200. Hence the difference of the Quotients is 300, and meaſuring the diſtance between my two ſtations A and H, ſuppoſe I find it [as before] 450 foot. This known, To finde the Diſtance K F, I ſay.

As the difference of the Quotients 300.
Is to the diſtance between my two ſtations K and I 450 foot.
So is my Quotient number made at the firſt ſtation 500.

To the diſtance of the (*Perpendicular*) baſe L, from the firſt ſtation A, 750 foot, from which I ſubſtract the diſtance between my two ſtations A and H, 450 foot, reſts 300 foot, for the diſtance of the (*Perpendicular*) baſe L, from the ſecond ſtation H, as was required.

So that if it were required to begin a Myne at A or H, for blowing up of the Tower L I. Then I ſay, that if

if you ſhall dig the ſaids Myne Horizontally from H to L, you muſt dig 300 foot from the ſaids point H, before you can come under the Tower at L. And if ye ſhould begin to dig your Myne at A, then you muſt dig 750 foot, before you ſhould be exactly under the ſaids Tower.

But in Mynes digging, for blowing up of a Tower or Caſtle: Suppoſe you begin at H. Then as you dig forwards for every ſix foot of length which you dig, you muſt riſe ſlope-wayes (above the levell of the entry at H) half a foot, or ſix inches; for the better carrying forth of the rubbiſh, and alſo for the more facile ingreſſe, and greater reſiſtance of the violence of the Powder, when you are to give Fire, &c.

This Concluſion is only practiz'd in time of War, againſt an enemy when beſieged in ſome ſtrong Caſtle, Tower, or Fort. Where Battering cannot prevail, uſually Myning will. But God of his mercy and grace grant us peace. Amen.

Laſtly, to finde the *Hypothenuſall* diſtance A K. I add the Square of A F, the heighth 5625, to the Square of the baſe F K, 562500. The Aggregate is 568125, whoſe *Square* root is 753 foot, 427——576, that is almoſt nine inches. In like manner, for the *Hypothenuſall* diſtance A I; the Altitude A E 75, its *Square* 5625, added to the *Square* of the baſe (F I 300) *viz.* 90000. The Aggregate is 95625, whoſe *Square* root is 309 foot, two inches and 998——1403 parts of an inch, as was required.

CHAP. XXVI.

To know exactly how far any Ship, Mark, or other Object is distant from you: Your self standing on some high Tower, Castle, or Hill, by the Sea-Coast.

THis, and the two preceeding Chapters, are of excellent use, for all such as shall have commited to their charge any Plat-form with Canons, either for shooting from, or against any place or object. For hereby you may exactly at the first view, know the distance to any *Ship* on the *Sea*, or Mark on the Land. So that having a Table of randoms made, and mounting your peece accordingly. There can no Vessel, or Object (though it be beyond point Blank, yet) if it be within the reach of your greatest randome, but you may (with your Cannons) at the first [firing] do execution, and never bestow vain shot: And therefore,

You must first know the true exact *Perpendicular* heighth of the Hill, Tower, or Castle (according as is shewed in the 14 Chapter) above the water or ground Level. Then standing on the top of your Tower, &c. hold up your Quadrant, looking diligently through both the sights until you espy the mark or object, whose distance you desire to know. And so observe the part cut by the Threed and Plummet. Which being known. To finde the required distance. *Say*, —— As the parts cut, is to the whole *Square*, or *Scale*; *So* is the *Perpendicular* heighth of the Hill, Tower or Castle, to the

the true distance, between the *Perpendicular* base of the saids Tower, Hill or Castle, and the object. ——But to finde the *Hypothenusal* distance, square both the Longitude

gitude and Altitude, and the ſquare root of the Aggr
gate, will be the *Hypothenuſal* diſtance required.

As for Example, Suppoſe it were required (ſtan
ing in the Tower at H) to finde the diſtances betwe
the *Perpendicular* Baſe L, and the object at I, and a
between the top of the Tower H, and the ſaids ma
at I. Wherefore holding up my Quadrant, and looki
diligently through the ſights thereof, until *I* eſpy t
Hull of the Ship, or that part of her that is next t
Water, as at I. At which time ſuppoſe the Thre
and Plummet fall on 10 parts of contrary ſhaddow
And ſuppoſe the Altitude of the Tower H L to be 1
foot. This known, To finde the diſtance of the
ſigned mark or object I, from the *Perpendicular* Ba
of the Tower at L, I ſay:

As the parts cut 10, Is to the whole ſide of t
Square 100.

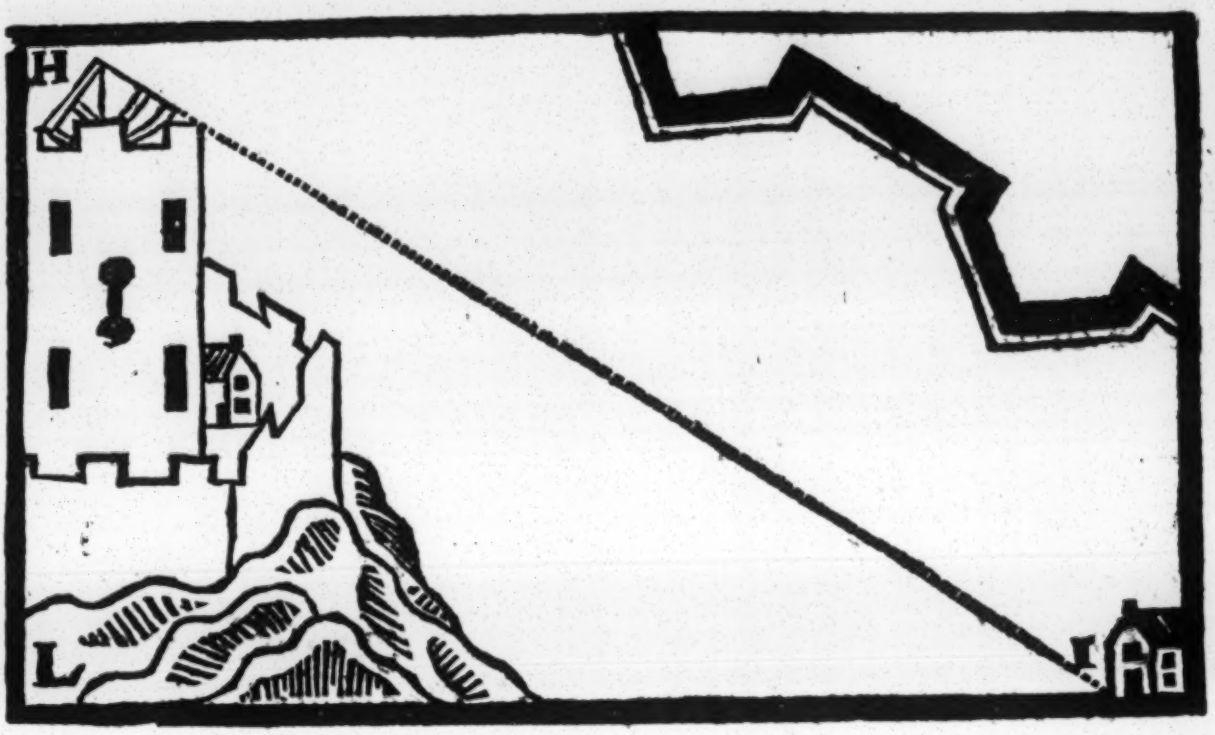
So is the Perpendicular Altitude of the Hill
Tower H L, 120 foot.

To the true diſtance between the Baſe of the Towe
and the object, *viz.* L I, 1200 foot.

Next, to find the *Hypothenuſal* diſtance (repreſent
in the Diagram by) H I, being the diſtance from t
top of the Tower H, unto the object or mark at
The Longitude or Diſtance L I, is, 1200 foot: whi
multiplied by it ſelf, the Product 1440000 is the ſqua
thereof.

In like manner, the Altitude of the Tower H L,
120 foot, whoſe *S*quare is 14400. Theſe two Squar
added together, the Aggregate is 1454400. who
Quadrate Root is 1006, and 1—5, part of an Inc
And ſo much is the *Hypothenuſal* line H I, or the d
ſtan

ſtance of the mark or object at I, from the top of the Tower at H, as was required.



Another Example, Suppoſe the Altitude of the Tower H L, to be 200 foot high, and that the Threed and Plummet did fall on four parts of contrary ſhaddow. Then the Longitude or Diſtance L I, will be found 5000 foot. For,

As the parts cut by the Threed and Plummet 4.
Is to the whole ſide of the *Square* (devided into) 100.
So is the (Perpendicular) heigth of the Hill or Tower H L, 200 foot.

To the true diſtance or length L I, between the Baſe of the Tower L, and the Object I, 5000 foot (which is a myle) as was required.

But to find the *Hypothenuſal* (or ſlopping) diſtance H I, between the top of the Tower H, and the object I, I take the Longitude L I, 5000, whoſe ſquare is 25000000

25000000, and adds the ſaids ſquare, unto the ſquare of the Altitude H L, 40000. The Aggregate is 25040000, whoſe *Square* Root is about 5004 foot, for the *Hypothenuſal* diſtance H I, as was required.

Thus, with your Quadrant, you may know all heights, depths and diſtances, acceſſible or inacceſſible; Together with the Suns Declination, Amplitude, Altitude, Azimuth and hour of the day, &c. in any Latitude or place of the earth whatſoever.

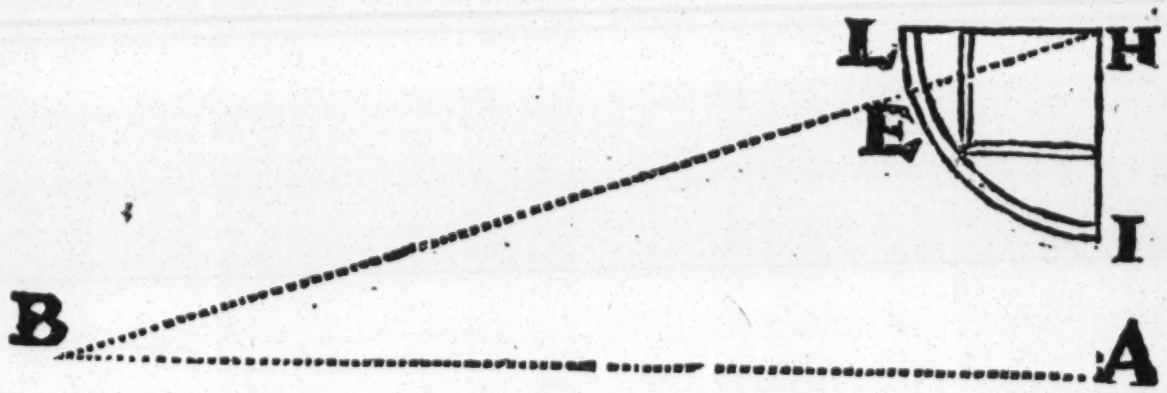
CHAP. XXVII.

To finde the exact diſtance to any viſible mark or object in the field, both Geometrically, Arithmetically, and according to Trigonometry.

FOr the more facile reſolution of this (and all ſuch like) Geometrical concluſion, and that the ignorant may meet with no obſcurity therein. *I* ſhall endeavour to be as plain, in the ſeveral Operations, as poſſibly *I* can. And therefore, you muſt firſt of all cauſe your Quadrant to ſtand faſt on the top of ſome ſtaffe (by means of ſome ſcrue, or vice) and upon the Center thereof (in ſtead of the threed and plummet) fix a ſmall Index (made of Wood, a little longer then the Radius of your Quadrant) which muſt turn about as occaſion ſhall ſerve: And upon the fiducial edge of the ſaids *Index*, muſt two ſuch ſights be placed, as are on the edge of the Quadrant, that through them you may look towards your object.——And yet in my own

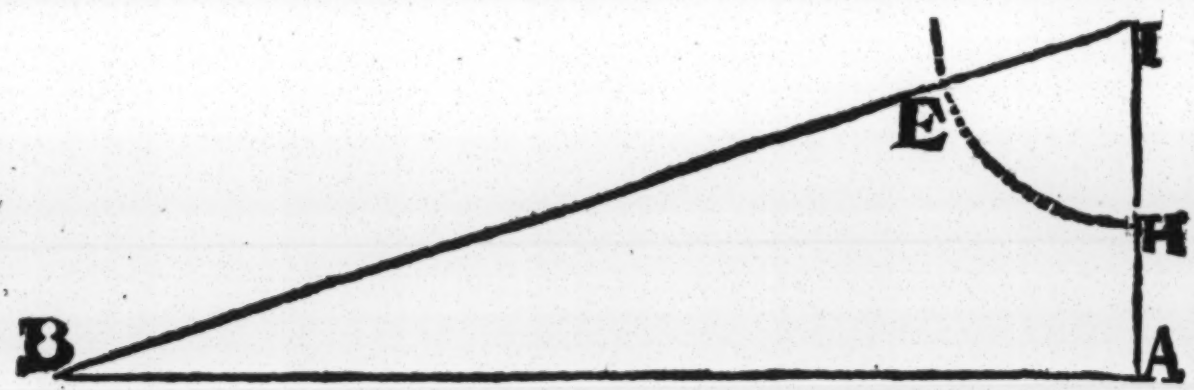
own frequent practice, when *I* have not had an *Index* fixt to my Quadrant, I have oft enough made uſe of the threed and plummet in ſtead thereof, and been as exact with it, as with the *Index*, and ſo may you do too.

Your Quadrant thus fixt upon a ſtaffe, and ordered as aforeſaid. Suppoſe *B* to be a mark or object in the fields, whoſe diſtance from your two ſtations A and H, is required.——To do this, thruſt your ſtaffe into the ground at A, and your Quadrant being fixt upon the top thereof, direct one of the ſides ſo, as it may exactly point to B, (keeping alwayes the Center of your Quadrant next your eye.) Then obſerve where the other ſide directs you (which will be alwayes from the right or left hand, ſide wayes towards ſome other place) and cauſe one ſet up another ſtaffe, a certain number of ſcores of ells or foots (the more the better) as here from A to H, and call it your ſtationary diſtance, which (being meaſured) we ſhall ſuppoſe to be 50 yards.



This done, take up your ſtaffe with the Quadrant upon it, (and ſet another in its room, as at A) then carry it to your ſecond ſtation at H, and there place your ſtaffe, ſtreight up, with the Quadrant fixt on the top

top of it. This done, turn your ſtaffe about (without touching the Quadrant) untill you eſpy (by that ſide thereof, which pointed from your firſt ſtation A, to the object B, as here from H to A) your firſt ſtation. This done, turn the index (or threed and Plummet if you have no Index) about, untill by the very edge thereof, you eſpy your mark or Object B. Then mark how many Degrees and minuts (upon the Limbe of the Quadrant) the ſaids Index or threed doth cut: which here wee will ſuppoſe to be 73 Degrees, 18 minuts. Which knowne; with the meaſured Diſtance between the two ſtations, *viz.* A and H, 50 yards. —— Then Geometrically, to finde the true diſtance of the Object B, from both your ſtations, you ſhall project it thus.

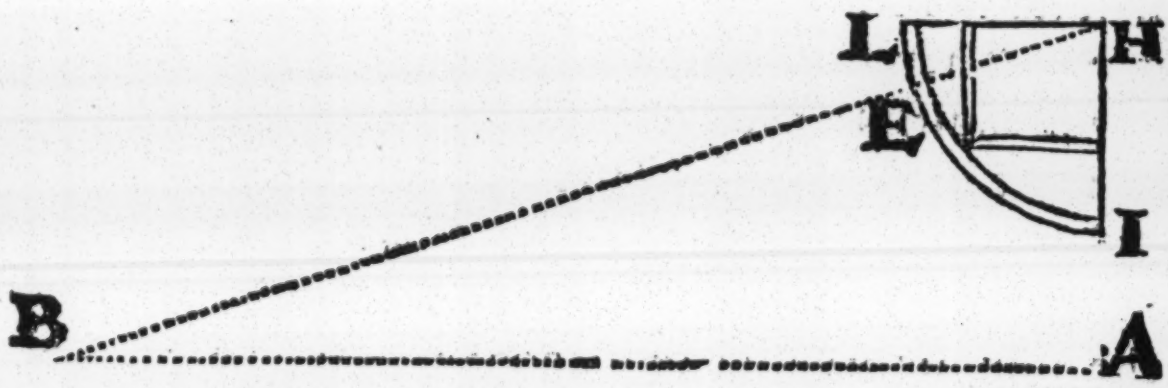


Take a ſheet or peece of clean Paper, and thereon, firſt draw the line A B, and upon the point A, raiſe the *Perpendicular* A H, (according as I ſhewed you in the third Chapter) then take 50 from a ſcale of equal parts, and ſet from A to H, and then open your Compaſſes to the Radius of your line of Chords (which, as I ſaid before, is alwayes 60 degrees) and with this diſtance, ſet one foot in the point H, and with the other deſcribe the arch I L. This done, take 73 deg. 18 min. from the ſaids line of Chords, and ſet this diſtance from I to L.

Laſtly,

Laſtly, lay a rule upon the two points H and L, and ſo draw the line H L B, untill it cut the line A B, in the point B. Then take the length of the line A B, and apply it to that ſcale of equal parts, whereof you made A H 50, and it will give 166, 2—3 yards, for the exact diſtance between the Object *B*, and the firſt ſtation A. In like manner, take the length of the other line, *viz.* H B, and apply it alſo to the ſaids ſcale, and it will give 174 yards, and ſo much is it between the ſecond ſtation H, and the Object *A*.

I have been the larger upon this operation, becauſe (it being once underſtood) makes way for the reſt following, and therefore I ſhall be the more breef therein; yet not ſo breef neither, but that the Ignorant (being expert in the premiſſes) may eaſily comprehend the ſame.



Now, *Arithmetically*, I mean by Calculation, to find the former diſtances of the ſaids mark or object *B*, from each ſtation. Wee ſhall ſuppoſe, that the index or threed, at the ſecond ſtation H, did cut 30 parts, upon the Geometrical ſquare, or ſcale of equal parts, (whereof the whole ſquare is devided into a 100 equal parts) and let the ſtationary diſtance A H, be (as before) 50 yards. Then to find the diſtance of the mark

or

or object B, from your first station A, say by the Golden Rule.

Anal. { As the parts cut 30, is to the whole Square 100;
So is the stationary distance A H 50 yards, to the true distance of the Object B, from your first station A, 166 yards. 2—3.

Then to finde the distance of the Object B, from the second station H; multiply the distance between your Object, and your first station, by it self; and also the distance between your two stations, by it self. This done, add these two Products together; and from their sum or Aggregate, extract the □ Square root, Which □ root, shall bee the distance of the Object B, from your second station I, as was required.

As for Example, Knowing the distance between my first station A, and the Object B, to bee 166 yards and 2—3. Therefore if you multiply it by it self (I mean, if you multiply 166 yards 2—3 by 166 and 2—3) The Product will be 27778 *ferè*. Likewise, Multiply the distance between your two stations A and H, *viz.* 50 by it self, the Product is 2500: Which added to 27778, the sum or Aggregate is 30278. Whose □ Square root (being extracted) is 174 yards *ferè*. And so much is the distance between the Object B, and the second station at I, as was required.

The Operation.

The □ Square of the side { A B, 166, 2—3 / A H 50 } is { 27778 *ferè* / 2500 }

whose Aggregate or sum is 30278, and consequently the □ root is 174 yards, *ferè*.

Lastly,

Laſtly, According to *Trigonometry*; you muſt know, that an oppoſite Angle (being known) gives an oppoſite ſide. And *è contra*, *i. e.* An oppoſite ſide (being known) gives an oppoſite Angle: And therefore in any right Angled Triangle: When you know any Angle, and the true length of the ſide oppoſite thereunto; the complement of the ſaids [known] Angle to 90 degrees, will give the length of the other unknown ſide, which is oppoſite thereunto. For in any right Angled Triangle whatſoever; where two Angles, and the ſide included between them, is all [three] known: Then the other two ſides will alwayes bee found, by this proportion, *viz.*

As any [known] Angle, is to its oppoſite ſide,
So is the Complement of the ſaids [known] Angle,
To the exact length of its oppoſite ſide required.

Theſe things, being thus [neceſſarily] explained for the better illuſtration of the premiſſes, I ſhall come next to the demonſtration and practice thereof. Wherein I ſhall be as plain and breef too, as poſſibly I can.

In the Triangle A B H, we ſhall ſuppoſe, that there is known; Firſt, The Triangle A H B 73 degrees, 18 minuts, (whoſe complement to 90 degrees, is the Triangle A B H, 16 degrees, 42 minuts. And) Secondly, The ſtationary diſtance, or ſide A H, 50 yards. Thirdly, The Right-Angled-Triangle H A B, 90 degrees. Hence to finde the ſides A B, and H B, (in the firſt Diagram) I ſay,

	d.	m.	
As the ſine of the Angle A B H,	16.	42.	9, 458427
Is to the Logarithm of its oppoſite ſide A H, 50 yards,			1, 698970

So

So is the ſine of the Angle A H B, 73. 18. 9, 981285

11, 680255

To the Logarithm of its oppoſite ſide A B, 166 yards, 2—3 } 2, 221828

Then to find the other ſide H B, I ſay,

d. m.

As the ſine of the Angle A B H, 16. 42. 9, 458427
Is to the Logarithm of the ſide A H, 50 yards 1, 698070

So is the (Radius, or) ſine of the Angle H A B, 90. 00. } 10, 000000

11, 691970

To the Logarithm of its oppoſite ſide H B, 174 yards, } 2, 240543

As in the Golden Rule, we alwayes multiply the ſecond number by the third, and devides the Product by the firſt. So in theſe Artificiall numbers, (in ſtead of Multiplication and Deviſion) wee (onely) adde the ſines and Logarithms of the ſecond and third numbers together, and from the Aggregate, ſubſtracts the firſt number, the remainder anſwers for the fourth proportional number required.

So in theſe two *Trigonometrical* Operations, you ſee, that the diſtance of the Object B, from your firſt ſtation A, is 166 yards. And in like manner, the diſtance of the ſaids Object B, from the ſecond Station H, is 174 yards, *ferè*.

Thus I have ſhewn you all the operations, for obtaining the exact diſtances of any place or mark in the Field,

Field, from both your ſtations. But I leave you to make choyce of them, not doubting but you will embrace and practice that way of operation which you find to be moſt familiar and eaſie.

CHAP. XXVIII.

To know what part of the external Superficies of a Hill ſide, is Levell with the bottome of a Coal-heugh, or Stone Quarrell, that is digg'd thereon.

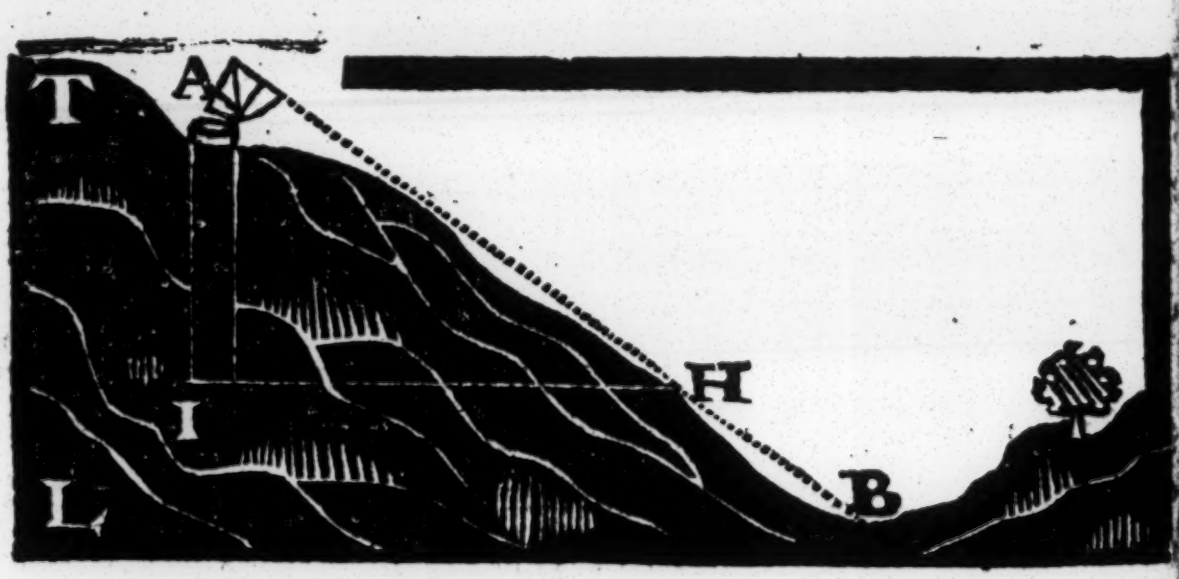
MAny are the inconveniences, hazards and damages, which thoſe perſons meet with, that dig deep in the earth: Whither for Coal, Lead, or other Minerals. For ſometimes their diſcenſion is *Perpendicular*, ſometimes ſlopping, and ſometimes Horizontal, &c. according as the Veins of the Earth are diſpoſed. Some parts being Clayiſh, or Graveliſh, there the deſcenſion is more facile; Other parts more Materiall, as Coal or Stons, &c. Both which are not alwayes of a like freeneſs; being ſometimes more hard, and ſometimes more ſoft, as is well known to Coalliers and Quarriers, &c.

But ſuppoſe they meet with no difficultie nor danger in their digging (downwards) but that the Coal or Stone may be freely and ſafely won, and the Rubiſh removed. Yet oftentimes Water (which the air in the Pit naturally ſucks to it) doth impede their progreſſe, endamages the Maſters purſes, and haſtens the Myners remotion with bag and baggadge.

Now

Now when theſe Heughs or Pits are digg'd upon Hill-ſides (as moſt commonly they are) if the Maſters or *Myners* knew what part of the external ſuperficies of the Hill-ſide were level with the bottom of the Heugh or Pit: then they might uſe means to withdraw the water, by cauſeing it to aſcend upwards, or elſe to go ſome other way, ſo that the progreſſe of the work might not be retarded.

Suppoſe therefore, that *B*, *H*, *A*, *T*, bee a Hill-ſide, and on a certain part thereof as at *A*, there is a Heugh or Pit ſunk, whoſe deepneſſe reaches to *I*, from which point *I*, a level line is to be ſo drawn, as that it may cut ſome part of the external ſuperficies of the *Hill*-ſide, as at *H*. Then the buſineſſe is, how to finde out (by Art) how far the mouth of the Heugh *A*, is from the ſaids level point H, that is to ſay, how many foot a man ſhall meaſure down the Hill, from the mouth of the *Heugh A*, before hee bee exactly level with the profundity thereof at *I*.



To do which, though there bee many wayes, yet I ſhall make choice of that which *I* ſuppoſe to bee moſt familia

familiar and easie. And therefore, set up a staffe (about three, four, or five foot long) as neer the brim of the Pit or *Heugh*, as you can safely stand, and upon the top of the saids staffe, cause your Quadrant so hang, that the Limb and Plummet may bee downwards. Then looking diligently through both the sights thereof, along the superficies of the Hill, down to the foot or lowest part thereof, as here from A (the mouth of the Heugh) downwards to B (the bottom of the *Hill*) untill you espy some mark (there) as *B* (which may happen to bee some great stone, or a tree, &c.) This done, mark where the threed and Plummet cuts the Geometrical square, and note the parts cut thereby (which in this example wee shall suppose to bee 12) and also the degrees and minuts upon the limb of the Quadrant. Which (here) wee shall likewise suppose to bee 6 deg. 50 min. 34 sec.

This known, measure the deepnesse of the Heugh or Pit, with a line; from the top of the foresaid staffe unto the bottom of the Heugh: which here (in this example) we shall suppose to be 90 foot, that is (after six foot for a fathom) 15 fathom, or 30 yards.

Now, to know the length of the Horizontal line (*H I*) that is to say, the distance between the bottom of the Heugh, and that part of the out-side of the Hill, which is level therewith. Say (by the Golden Rule) thus——— If the parts cut 12, give the whole square 100; what shall the Profundity of the Heugh *A I* 90 foot give? *Anſ.* Multiply and devide, and the Quotient will bee 750 foot: that is 250 yards for the length of the Horizontal (or level) line *H I*.

This done, to find the length of the *Hypothenuſall*

(or sloping) line A H. Adde the Square of (*I H* 750, *viz.* 562500.) the Horizontal line, to the Square of the Heughs deepth (A *I* 90, *viz.* 8100.) and from the Aggregate (or sum) extract the Square Root (as I shewed you in the preceeding Chapter) and that will be the length between the top of the foresaids staffe, and that part of the hills superficies, which is levell with the bottom of the saids Heugh, which the following operation demonstrats.

The □ Square { H I, 750 } foot, is { 562500
of the side { A I 90 } foot, is { 8100

The Sum, or Aggregate of both these is 570600

whose *Square* root is 755 foot, and four inches, for the length of *A H* the *Hypothenusal* line.

They that understand not this way of Operation, may practice the same Geometrically [by means of your lines of Chords, and equal parts] or according to *Trigonometry*. Both which I have sufficiently demonstrated in the preceeding Chapter. Besides, they have an universal application, in observation of all Lengths, Depths, and Distances, or any Angles whatsoever. But

I shall

I ſhall [in this Chapter] make application [only] of the Calculations, according to *Trigonometry*.

In the Triangle *A I H*, are given [1,] the Triangle *A H I*, ſix deg. 50 min. 34 ſec. whoſe Complement [to 90 degrees] *viz.* 83 deg. 09 min. 26 ſec. is the other Angle *H A I*. [2,] the right Angle *A I H*, 90 degrees, and [3,] the ſide *A I*, 90 foot. Then to finde the ſide *I H*, I ſay,

As the ſine of the Angle oppoſite, to the known ſide (or profundity of the Pit A I) is to the Logarithm of the depth of the ſaids known ſide; So is the ſine of the Angle (made) at your ſtation, (being the mouth of the Pit at A) to the Logarithm of the length of the Horizontal line H I.

But becauſe I would make all things as plain to the meaneſt capacity, as poſſibly I can: Therefore I ſhall here give you a *Synopſis* of the whole Calculations thereof, according to that excellent doctrine of *Trigonometry*. In which Operation, I ſhall purpoſly omit the ſeconds, and only make uſe of degrees and minuts, as followeth.

	d.	m.	
As the ſine of the Angle A H I,	6.	50.	9, 075479
Is to the Logarithm of its oppoſite ſide A I, 90 foot			1, 954242
So is the ſine of the Angle H A I,	83.	9.	9, 996903
			11, 951145
To the Logarithm of its oppoſite ſide H I, 750 foot, *ferè*.			2, 875666

So that if it were required to dig a Myne, or to work in this Coal-heugh, all along upon a direct Horizontal (or Levell) line, from the profundity of the *Pit I*: Then *I* say, that when they have wrought in the *Pit*, on a ſtreight line, 750 foot (or 126 fathome) they would at laſt come to the very external Superficies of the hill at *H*, which would be another Vent or *Paſſage* to, or from, the profundity of the *Pit I*.

But becauſe this is not the ſpecial thing here intended, notwithſtanding that it may be of ſingular uſe and importance, and accordingly (by an Ingenious man) might be applyed to ſeveral good purpoſes, either in time of Peace or War. *I* ſhall therefore leave the various Uſes and Applications thereof, to thoſe whom it may happen to concern; and ſhall next come to the matter and purpoſe principally intended, *viz.* To finde that part, of the external Superficies of the Hill-ſide, which is Levell with the profundity of the Pit *I*. Therefore, ſeeing we know the profundity A *I*, to be 90 foot, and the *Horizontal* line *H I*, 750 foot. Then to find the *Hypothenuſal*, or third ſide A *H*, *I* ſay,

	d. m.	
As the ſine of the Angle A H *I*,	6. 50.	9, 075479
Is to the Logarithm of its oppoſite ſide A *I*, 90 foot,		1, 954242
So is the ſine of the Angle A *I* H,	90. 00.	10, 000000
		11, 954242
To the Logarithm of its oppoſite ſide A H, 755 foot, 1–3		2, 878763

Laſtly

Lastly, *If* you take a line, and begin at the top of the staffe, and measure streight down the Hill 755 foot and 4 inches, you will come to that exact point of the Superficies of the *Hill* (at *H*) which is Level with the bottome of the *Heugh* at I. Which is a conclusion of great consequence, to those who are concern'd therein, whither it be for Mineralls, Stone, Coal or Lead, &c.

CHAP. XXIX.

To finde the Suns Azimuth, and hour of the day most exactly, easily and Artificially without any Instrument: Otherwise then is taught in the 12, 13, 21 *and* 22 *Chapters.*

THis is most easily performed by *Trigonometry*; for although you have no Quadrant, lines of Chords, or other Instrument: Yet you may find the Suns Azimuth, and hour of the day, (onely by help of a small Table of Artificial Sines) at all times of the day, and in all places of the World, thus, *viz.* By knowing the Latitude of the place, [according to the 9 Chapter] and the Suns Declination (according to the 17 Chapter) and the Suns Altitude, forenoon or afternoon [which you are taught how to find by the eighth Chapter.]

These things being known, Consider, whither the Suns declination be Northwards or Southward, [which the 17 Chapter will shew you,] if it be Northwards. Substract the Suns declination from 90 degrees, and the remainder will be the Suns distance from the North-

Pole

Pole of the World. But if it be Southwards, adde the Suns declination to 90 degrees, and the Sum or Aggregate, will be his distance from the North-Pole of the World; of both these, I shall shew you examples, in their proper place.

To finde the Suns Azimuth, Observe this Generall Rule, *viz.* Take the Complement of your Latitude, the Complement of the Suns Altitude observed, [whither forenoon or afternoon] and the distance of the *Sun* from the North-Pole of the World, and adde all these three [in degrees and minuts] together into one sum: And from the half of that sum, substract the *Suns* distance from the Pole, and so note the remainder or difference. And then say, *As the Radius* [*or sine of*] 90 *degrees, is to the Co-sine of the Suns Altitude; So is the Co-sine of the Latitude, to a fourth sine.* Then say again,

As that fourth sine, is to the sine of the half sum, So is the sine of the difference, to a seventh sine. The half of which (the Radius being first Mentally added) shall be the sine of an arch; whose Complement being doubled, shall shew the number of degrees and minuts of the Suns Azimuth (alwayes) from the North part of the Meridian, towards the South.

For better Illustration of the premisses, *I* shall here make application of the first *Example* (in the 21 Chapter) to see how the same will agree with *Trigonometry.*

Example, When the Suns Declination is Southwards, which here we will suppose to be the first Example, mentioned in the saids 21 Chapter, page 54. where the Suns Declination is 11 deg. 30 min. Southwards.

Which

Which 11 deg. 30 min. added to 90 deg. the ſum is the diſtance of the ⊙ from the North-Pole of the World, *viz.* 101 deg. 30 min.

This being cleared, we ſhall apply our Operation to that firſt Example, mentioned page 54. Where the Latitude of the place is ſuppoſed to be 56 d. 00 min. and the Suns Altitude obſerved (in the moning) 17 deg. 30 min. And the Suns Declination, Southward, 11 deg. 30 min. Which added to 90 deg. the ſum 101 deg. 30 min. is the diſtance of the Sun from the North-Pole of the World. This diſtance of the Sun from the Pole, added, to the complements of the Latitude, (*viz.* 34 d. 00 m.) and the ⊙ Altitude obſ. (*viz.* 72 deg. 30 min.) the ſum will be 208 d. 00 m. whoſe half ſum is, 104 d. 00 m. and the difference between the ſaids half ſum, and the diſtance of the ⊙ from the Pole, 2 d. 30 m. This known, I ſay.

As the Radius 90 d. Is to the Co-ſine of the Latitude 56 d. So is the Co-ſine of the ⊙ Altitude obſ. 17 d. 30 m. To a fourth ſine, *viz.* 9,726981. Then ſay, 2. As the ſine of the fourth arch, 9,726981. Is to the ſine of the half ſum, 104 d. So is the ſine of the difference, 2 d. 30 m. To a ſeventh ſine, which with the Radius added, is, 18,899602. The half of which, (*viz.* 9,449801) is the ſine of 16 d. 22 m. whoſe complement 73 d. 38 m. doubled, is 147 d. 16 m. for the ⊙ Azimuth from the North. From which if you ſubſtract 90 d. the remainder, 57 d. 16 m. will be the ⊙ Azimuth from the Eaſt towards the South, as was required.

Laſtly, To finde the hour and minut of the day, add the Complement of the Latitude, and the Complement of the Suns Altitude, together with the diſtance

of

of the Sun from the North-Pole of the world, all three into one ſum. And from half the ſum thereof, ſubſtract the complement of the Suns Altitude, and (ſo) note the difference. And then ſay,

1. As the Radius, is to the ſine of the Suns diſtance from the Pole; ſo is the Co-ſine of the Latitude, to a fourth ſine.

2. As that 4th ſine, is to the ſine of the half ſum; ſo is the ſine of the difference, to a 7th ſine. Unto which adde the Radius, (*viz.* 10,000000.) and the half of the ſum, will be the ſine of an arch, whoſe complement doubled: the degrees and minuts thereof (reduced into time by allowing 15 deg. to an hour, *&c.*) will ſhew the time of the day from the South part of the Meridian, *viz.* 12 a clock. As for Example,

In the ſecond Example of the 22 Chapter, page 55. The Latitude of the place is ſuppoſed to be 56 deg. and the ⊙ Altitude obſerved in the afternoon, 33 d. 15 m. And the ⊙ Declination Northwards, 20 d. 12 m. Hence according to the former rule, the time of the day, from the South, will be found, 60 d. 4 m. That is, (being reduc'd into time) 4 a clock in the afternoon. But if it had been in the forenoon, it would have been 8 a clock in the morning.

Here note, That in finding the hour of the day or the ⊙ Azimuth by the Quadrant, mentioned Chapter 21 and 22, you muſt know, that that ſide of the Quadrant, whereon the ſights is plac'd, repreſents alwayes the Meridian, or 12 a clock hour line: That's to ſay, the true South or North. And the other ſide of the Quadrant where the line of ſines is plac'd, repreſents the points of Eaſt and Weſt; and alſo the ſix a clock hour line, both for morning and evening.

CHAP.

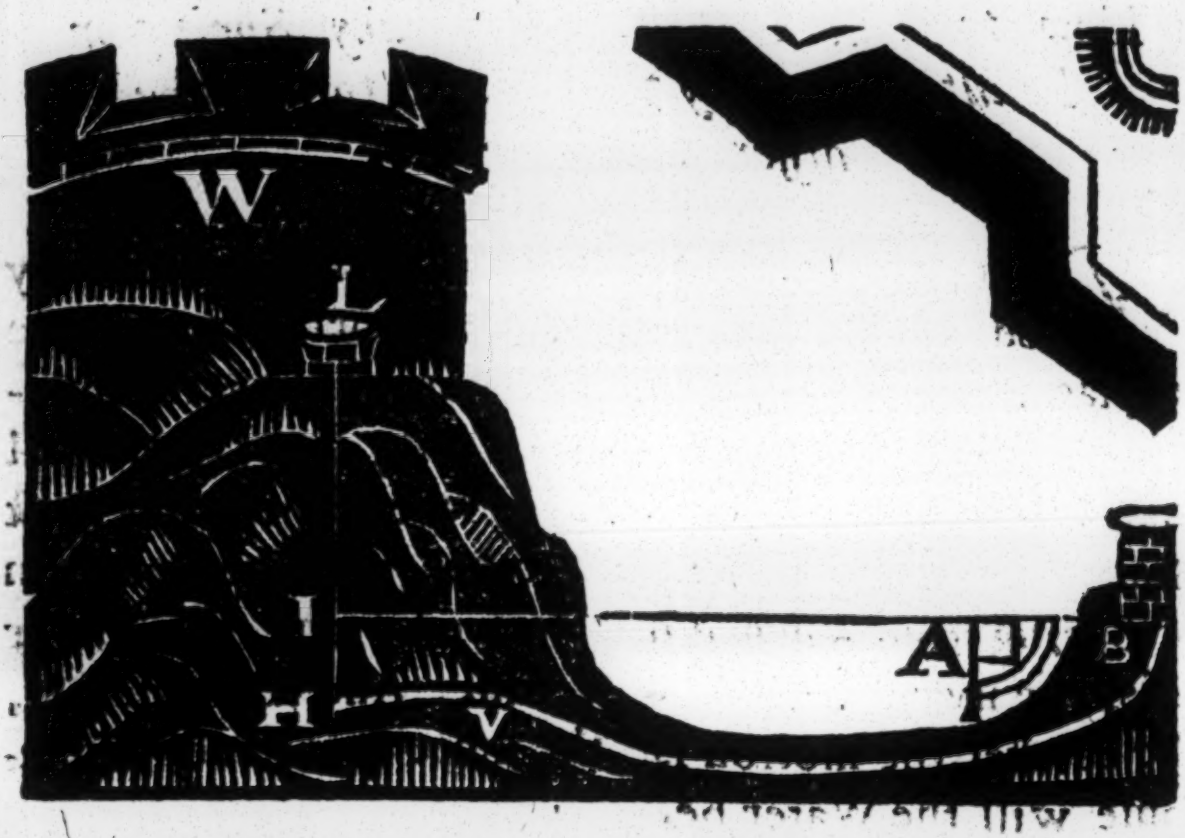
CHAP. XXX.

How to Conduct Water from any Spring or Fountain, to any place, and to find the difference of Levells.

WAter is of such a Nature (though it bee a heavy body) as that it may be transported from place to place, by means of Pipes, and brought over Mountains and *Hills* how high soever they bee: provided that the Vent, or end of the Pipe, where the water must issue forth: be inferiour and lower, then the Fountain or Spring from whence it is derived; and the lower it is, the more freely it will run. And consequently, the quicker the motion is, the more pure and wholesome will the Water be.

Now, seeing the whole Earth and *Sea* makes a perfect Glob; it must needs follow then, that the motion of Water is not in a level right line; because, if it were so (considering it is a contingent or touch line) it must needs be carried above the Circumference, and the farther it is extended, the farther it should be from the Center. Therefore it must deviate from a level right line, and move another way; and that we finde (in all it's courses) is still downwards (unlesse violently forced contrary to it's nature) keeping an uniform and equidistant motion from the Center, describing (as it goes) an *Arch* or part of a Circle. Which Circle or motion (in regard of the greatnesse of the Earth and Water) differs not sensibly from a level right line.

line. And yet in conveying Waters any great distance, very experience will bewray an error. It remains therefore to find out the exact difference between the right line level, and the Circular Water level.



In the following Figure, suppose B to be a Fountain or Spring; from whence it is required to carry the Water thereof to the Fort W, the distance between them, we shall suppose to be two Milles, that is 2000 Geometrical paces, every pace being five foot, &c. and let *A* be your station, where your eye is level with the bottom of the Fountain *B*, where holding up your Quadrant to your eye, cause the threed and Plummet to fall upon the side-line of your Quadrant, I mean, at the beginning of the degrees upon the limb: and then looking through both the sights towards the Hill and Fort W, observe what part of the saids Hill you do espy, which here we shall suppose to bee I, under the

Well

Well L, then you may conclude, that the ſaids point I, is exactly level in a right line from the Fountain B. And ſuppoſe H to be the Water level, that is to ſay, the higheſt Point that any Water will naturally run at, being conveyed by Pipe from B. Then the line *I H*, is this difference of levels required, which you ſhall thus finde out.

Multiply the diſtance of the Fountain from the place where you would convey your Water, by it ſelf; and the product added to the *Square* of the Earths Semidiamiter: And from the *Sum*, extract the *Square*-root. And laſtly, from the ſaids root, ſubſtract the Earths Semidiamiter, the remainder will be the difference of Levels required.

But, becauſe every man cannot extract Square-roots, you ſhall do it more plainly, thus, *viz.* for every *Italian* mile, (which is a 1000 Geometrical paces, every pace being five foot, &c.) that your Fountain is diſtant from the place, where you would convey your Water, you muſt allow 60 inch, that is five foot, and for every half mile, allow 30 inches, *&c.*

As for Example, the diſtance *B I*, being ſuppoſed two miles, Therefore, I allow ten foot for the difference of Levels, and ſo much is the line *I H*, that is to ſay, the Water Level *H*, is under the other Level at *I*, ten foot. So that if it were required to know, how deep to ſink a Well at L, in the Fort *W*, to receive this Fountain water from *B*, you muſt firſt know the true Altitude of the ground, plate of the Fort, above the Level *I*, which you are ſufficiently taught to find, without Inſtrument, by the 14 Chapter, and by your Quadrant, according to the 24, or 25 Chapters. I ſay, having found

found the foresaids heighth, add unto it the foresaids difference of Levels, and the Sum of these two, will shew the profundity *L H*, that is to say, so many foot deep it were requisite to sink a Well in the Fort at L, before it could be capable to receive Water from the Fountain *B*. As was required.

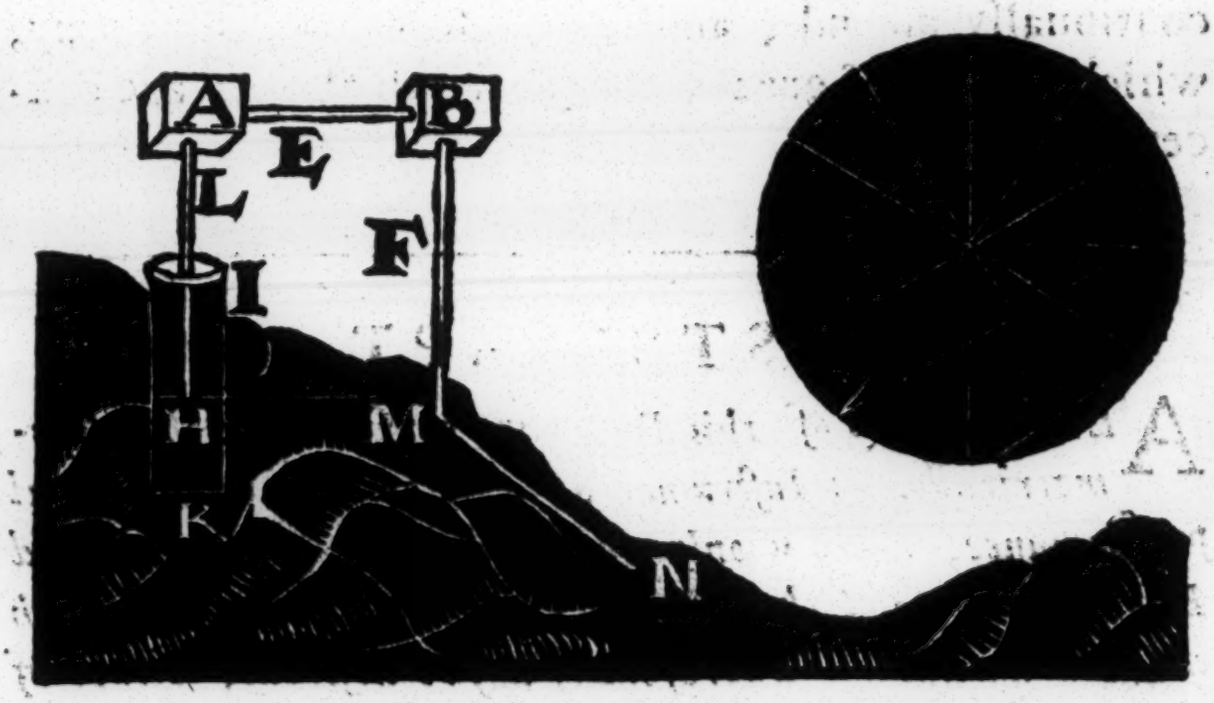
CHAP. XXXI.

How to make water in a Heugh or Pit continualy to ascend (by means of a Cistern only) without strength or the help of Buckets or Pumps.

THis Conclusion is most manifest upon such Heughs or Pits, which are scituate upon Hill-sides, where there is a great down-with upon some side thereof, that thereby there may be an addition of Pipes, according as the Water abates in the *Pit*: For that end of the Pipe where the Water issues forth, must alwayes be inferiour to the Water in the Pit: so that a while before the saids Water in the Pit, become Level with the vent of the Pipe, you must have several *Pipes* in readinesse, that you may joyn one to the end of the saids vent, and so often as necessity shall require it, and by this means the Pit will never leave running.

Wherefore, *Suppose* I K, be the Heugh or *Pit*, out of which it is required to cause water continually to ascend. To do which, Let there be made a Receiver or Cistern as A, which may contain four or five Gallons, (more or lesse, according to the greatnesse or smal-

ſmalneſſe of your *Pipe*,) this Ciſtern would be made very cloſe that no Air may enter it: unto it you muſt faſten your *Pipe* L, ſo long as it may reach, and be below the *Superficies* of the water in the *Pit*, as at H, which end H, is to reſt on ſome Iron Grate, and the end thereof ſtrongly ſtopped with Cork, that no water come into it, and ſo made that, you may draw it forth at pleaſure. This done, let there be made another Ciſtern as B, which may be communicative to A, by help of the *Pipe* E. From this Ciſtern B. muſt come another *Pipe* as F M, which muſt deſcend (to M) below the Level of the water in the *Pit*, as much as is M) to the end of this *Pipe* at M, thruſt in a ſtrong Cork, that may let no water out till you deſire. This done, to make uſe of it, fill the Ciſterns A and *B*, full of water, and cloſe it carefully again that no air get in.



Then when you would have it run, pull out the Cock firſt at M, then while the water at B deſcends to M, pull out the other Cock at H, & for ſe arthere ſhould be

be vacuity in the Ciſtern B: Nature (which abhors it) will ſupply that emptineſſe immediatly out of the Ciſtern A. And leaſt there ſhould be any emptineſſe in A, it will quickly be furniſhed out of the Heugh or Pit H: thus it will run continually night and day, and never ceaſe, if the ſpring of the water be greater then the Pipe. But if the Pipe be greater then the ſaids ſpring, the water will run no longer, then it becomes Level within the Pit, unto the vent without: and for that cauſe, you (having your Pipes in readineſſe) may fix another Pipe to the end of the ſaids vent, and then the water will run ſtill, till it come to that Level of the vent, then you may add another as from M to N, *&c.* But this muſt be done alwayes, before the water in the Pit become Level with the vent: Thus if you carefully obſerve the premiſſes, you will ſee that the water will continually aſcend, and then deſcend another way, which may be of great conſequence to all that are concern'd therein.

POSTSCRIPT.

ALL the Works of this Book are performed either Geometrically, or Inſtrumentally. For the Geometrical performance, there is only required a line of Chords and Equal parts, and the Inſtrumental part is performed with a Quadrant, &c. *Therefore if any be deſirous, either of lines of Chords, Equal parts, or Quadrants,* &c. *they may enquire for them at the Printing-Houſe at the foot of the Kirk-Heugh in* Edinburgh.

FINIS.

The *Stationers* to the Reader.

CONſidering the ſingular Uſe and Importance, which this Book of *Practical Geometry* (publiſhed by Mr. *Corſs* Mathematician) doth bring to moſt Trades and Functions, either in time of Peace or War; we have therefore Printed the ſame. And becauſe the Expence of cutting the Figures is conſiderable, as alſo the ſmall number of the Impreſſion. Therefore it hath occaſioned the Price thereof, to riſe above the ordinary Rates of other Books, formerly Printed by Us.

ERRATA.

Page 52, line 25, for 34 min, read 36 min. and l. 32, r. 36 min. p. 53, l. 9, r. 52 deg. 6 min. p. 54, l. 9, r. 57 deg. 16 min. l. 13, r. 38 deg. 8 min. l. 14, r. 60 deg. 10 min. p. 55, l. 15, r. 10 deg. 52 min. l. 23, r. 16 deg. 37 min. p. 70, l. 8, r. L A. l. 10, r. H & A, p. 71, l. 21, r. A I. l. 22, for A F, r. I L. l. 23, for F K, r. L A. l. 26, for A I, r. H I, afterwards in the ſame line, for A E, r. I L. l. 27, for F I, r. L I. p. 74, l. 5, for H, r. L. l. 6, for L, r. A. l. 7, for H, r. L. l. 13, for H L, r. A L. l. 16, for L, r. A. l. 20, for H, r. A. l. 22, for L I, r. A I. l. 24, for H I, r. L I. l. 25, for H, r. L. l. 26, for L I, r. A I. l. 29, for H L. r. A L. l. 33, for H I, r. L I. p. 75, l. 3, for H, r. L. l. 4, for——of the r. of this. p. 78, l. 18, for A H, r. A I. l. 20, for A to H, r. A to I. l. 23, for H, r. I. l. 24 for I L, r. H E. l. 26, for I to L, r. H to E. p. 79, l. 2, for H and L, r. I and E. l. 3, for H L B, r. I E B. l. 5, for A H, r. A I. l. 9, for H B, r. I B. l. 11, for H, r. I. p. 80, l. 16, for I, r. H. l. 27, for I, r. H. p. 82, l. 9, for 1. 698070, r. 1,698970. l. 12, for 11, 691970, r. 11, 698970.